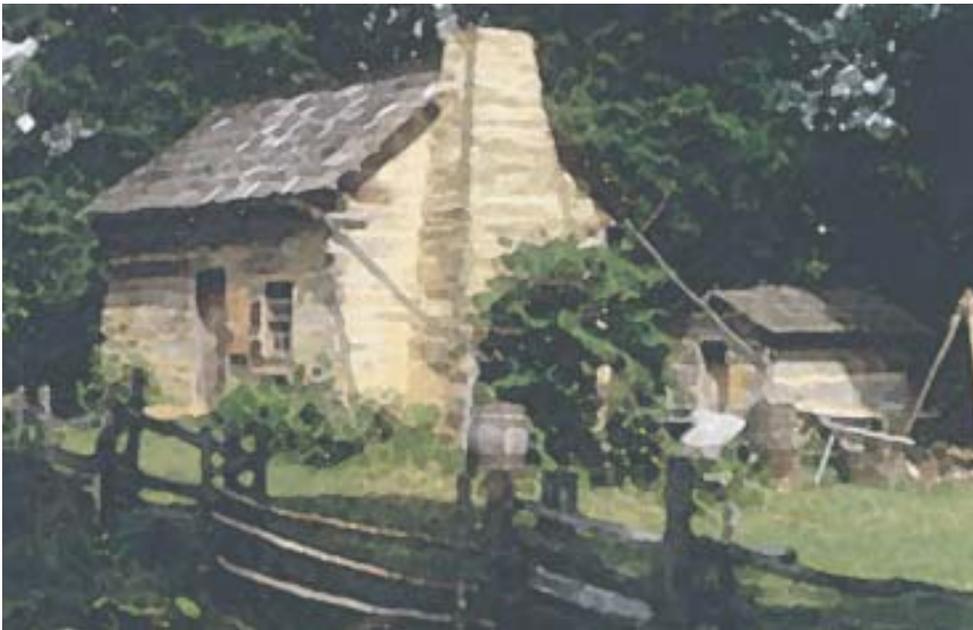


In cooperation with the National Park Service

# **Reconnaissance of Surface-Water and Ground-Water Quality at the Lincoln Boyhood National Memorial near Lincoln City, Indiana, 2001–02**



Scientific Investigations Report 2005–5066

**U.S. Department of the Interior  
U.S. Geological Survey**

**Cover.** Illustration adapted from National Park Service photo of reconstructed cabin at Lincoln Living Historical Farm, site of Thomas Lincoln's Indiana farm, near Lincoln City, Indiana.

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By Paul M. Buszka and Kathleen K. Fowler

Prepared in cooperation with the National Park Service

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**U.S. Department of the Interior  
U.S. Geological Survey**

**U.S. Department of the Interior**  
Gale A. Norton, Secretary

**U.S. Geological Survey**  
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U.S. Geological Survey, Reston, Virginia: 2005

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## Conversion Factors, Water-Quality Units, and Abbreviations

<b>Multiply</b>	<b>By</b>	<b>To obtain</b>
<b>Length</b>		
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
<b>Area</b>		
acre	0.4047	hectare (ha)
acre	0.004047	square kilometer (km <sup>2</sup> )
<b>Volume</b>		
cubic meter (m <sup>3</sup> )	264.2	gallon (gal)
liter (L)	0.2642	gallon (gal)
milliliter (mL)	0.03381	ounce, fluid (oz)
cubic foot (ft <sup>3</sup> )	0.02832	cubic meter (m <sup>3</sup> )
gallon (gal)	3.785	liter (L)
<b>Flow rate</b>		
cubic foot per second (ft <sup>3</sup> /s)	0.02832	cubic meter per second (m <sup>3</sup> /s)
gallon per minute (gal/min)	0.002228	cubic foot per second (ft <sup>3</sup> /s)
gallon per minute (gal/min)	3.785	liter per minute (L/min)
gallon per minute (gal/min)	0.0000631	cubic meter per second (m <sup>3</sup> /s)
<b>Mass</b>		
microgram (∞g)	0.00000003527	ounce, avoirdupois (oz)
milligram (mg)	0.00003527	ounce, avoirdupois (oz)
gram (g)	0.03527	ounce, avoirdupois (oz)
kilogram (kg)	0.002205	pound, avoirdupois (lb)
<b>Pressure</b>		
atmosphere, standard (atm)	101.3	kilopascal (kPa)

Temperature in degrees Celsius (°C) can be converted to degrees Fahrenheit (°F) as follows:

$$^{\circ}\text{F} = (1.8 \times ^{\circ}\text{C}) + 32$$

Vertical coordinate information is referenced to the National Geodetic Vertical Datum of 1929 (NGVD 29).

Horizontal coordinate information is referenced to the North American Datum of 1927 (NAD 27) in figure 3 of this report and to the North American Datum of 1983 (NAD 83) in figures 1, 2, and 4.

Altitude, as used in this report, refers to distance above the vertical datum.

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius ( $\mu\text{S}/\text{cm}$  at 25°C).

Concentrations of chemical constituents in water are given in milligrams per liter (mg/L) or micrograms per liter ( $\mu\text{g}/\text{L}$ ).

Milligram per liter is a unit expressing the concentration of chemical constituents in solution as weight (milligrams) of solute per unit volume (liter) of water.

A concentration of one thousand micrograms per liter is equivalent to one milligram per liter. For concentrations less than 7,000 mg/L, the numerical value for milligrams per liter is the same as for concentrations in parts per million.

A milliequivalent is defined as a weight of a chemical substance, divided by the formula weight of its composition elements and the assumed charge of the species. For example, calcium and magnesium have assumed charges of 2 and sodium and potassium have assumed charges of 1. The proportion of major cations and anions in water samples are graphically described in this report as concentrations in milliequivalents per liter.

A nephelometric turbidity unit or NTU is a unit of measure used to report the turbidity of water. Turbidity is a measure of the cloudiness of water and is measured by the amount of light that is scattered and absorbed instead of transmitted through the water by a standard light-measuring device, or nephelometer.

Bacteria are microscopic unicellular organisms, typically spherical, rodlike, or spiral and threadlike in shape, often clumped in colonies (col).

*Escherichia coli* (*E. Coli*) bacteria are present in the intestine and feces of warm-blooded animals. *E. coli* are a member species of the fecal coliform group of indicator bacteria. Indicator bacteria for presumptive identification and enumeration are cultured on selective media after filtration of several different sample volumes onto gridded membrane filters. In the laboratory, they are defined as those bacteria that produce yellow or yellow-brown colonies that remain so when placed on a filter pad saturated with urea substrate broth for 15 minutes after resuscitation at  $35.0 \pm 0.5^{\circ}\text{C}$  for 2 hours and primary culturing for 22 to 24 hours at  $44.5 \pm 0.2^{\circ}\text{C}$  on mTEC medium. Concentrations of bacteria are given in colonies per 100 milliliters (col/100mL).

## Abbreviations and acronyms used in this report:

<u>Acronym</u>	<u>Description</u>
DI	Deionized
<i>E. coli</i>	<i>Escherichia coli</i>
IDEA	Inventory Data Evaluation and Analysis
IDEM	Indiana Department of Environmental Management
N	Nitrogen
NADP/NTN	National Atmospheric Deposition Program National Trends Network
NPS	National Park Service
NWS-COP	National Weather Service Cooperative Observer Program
P	Phosphorus
PTFE	Polytetrafluoroethylene
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey



# Reconnaissance of Surface-Water and Ground-Water Quality at the Lincoln Boyhood National Memorial near Lincoln City, Indiana, 2001–02

By Paul M. Buszka and Kathleen K. Fowler

## Abstract

In cooperation with the National Park Service, the U.S. Geological Survey investigated water quality of key water bodies at the Lincoln Boyhood National Memorial near Lincoln City in southwestern Indiana. The key water bodies were (1) a stock pond, representing possible nonpoint agricultural effects on water quality; (2) an ephemeral stream, representing the water quality of drainage from forested areas of the park; (3) parking-lot runoff, representing water quality related to roads and parking lots; (4) an unnamed ditch below the parking lot, representing the water quality of drainage from the parking lot and from an adjacent railroad track; and (5) Lincoln Spring, a historical ground-water source representing ground-water conditions near a former diesel-fuel-spill site along a rail line. Water samples were analyzed for pH, temperature, specific conductance, and dissolved oxygen and for concentrations of selected major ions and trace metals, nutrients, organic constituents, and *Escherichia coli* bacteria.

Surface-water-quality data of water samples from the park represent baseline conditions for the area in relation to the data available from previous studies of area streams. Specific-conductance values and concentrations of most major ions and various nutrients in surface-water samples from the park were smaller than those reported for samples collected in other USGS studies in areas adjacent to the park.

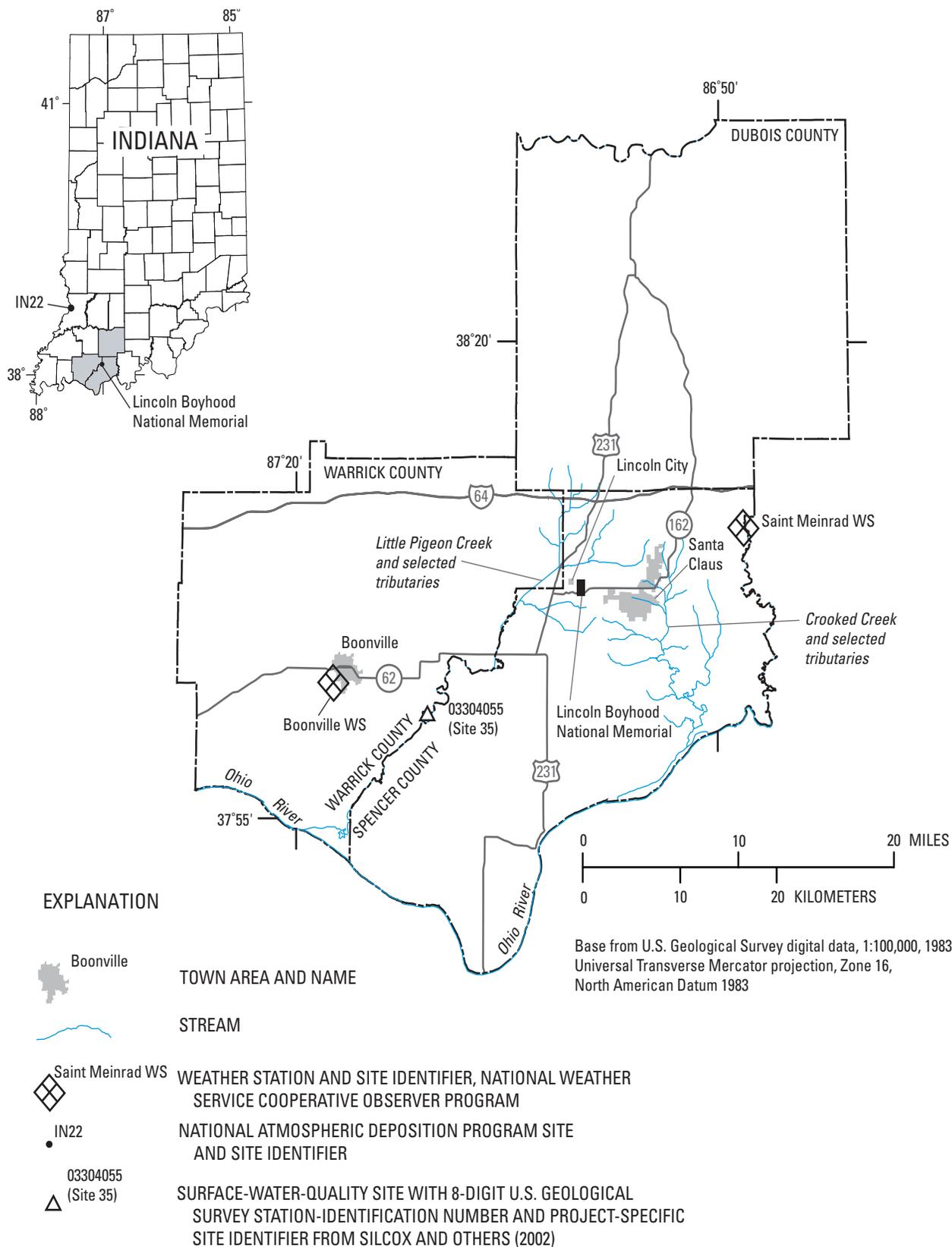
Water-quality-management issues identified by this investigation include potentially impaired water quality from parking-lot runoff, unknown effects on surface-water quality from adjacent railroads, and the potential impairment of water quality in Lincoln Spring from human influences. Parking-lot runoff is a source of calcium, alkalinity, iron, lead, and organic carbon in the water samples from the unnamed ditch. Detection of small concentrations of petroleum hydrocarbons in water from Lincoln Spring could indicate residual contamination from a 1995 diesel-fuel spill and cleanup. The concentration of nitrite plus nitrate in water from Lincoln Spring was 16.5 milligrams per liter as nitrogen, greater than the State of Indiana standard for nitrate in drinking water (10 milligrams per liter as nitrogen). Lead concentrations in samples from the stock pond, parking-lot runoff, and the unnamed ditch exceeded the Indiana chronic aquatic criteria.

## Introduction

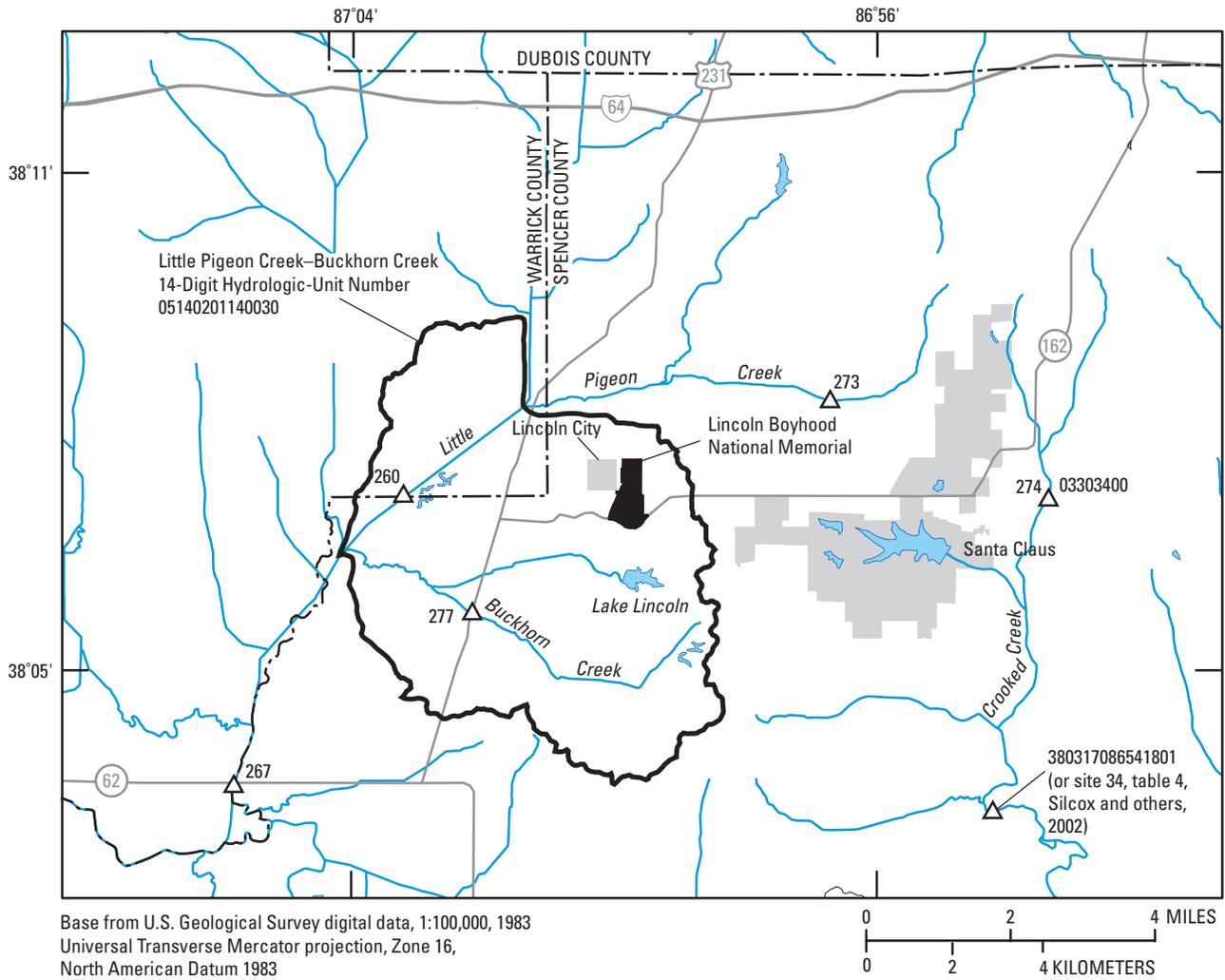
The mission of the National Park Service (NPS) is to preserve the natural and cultural resources and values of the National Park System for the enjoyment, education, and inspiration of this and future generations (National Park Service, 2004). An important part of this mission is to characterize the environmental resources that contribute to the particular purpose or use of each park within the system. In 1992, the NPS established a nationwide Level 1 Water Quality Inventory and Monitoring Program to obtain baseline water-quality information and to assess possible water-quality problems in national parks and monuments (park units) throughout the United States (National Park Service, written commun., January 1993). Key water bodies identified as part of that program are essential to the cultural, historical, or natural-resources management themes. To better characterize these resources, the NPS has been conducting assessments of water quality at park units under the Inventory Data Evaluation and Analysis (IDEA) program to identify baseline conditions associated with water resources within the park units (National Park Service, 1999).

The NPS, which manages the Lincoln Boyhood National Memorial (hereafter called “the park”) (fig. 1), determined in a previous inventory that there were no water-quality data from key water bodies within the park that could help characterize surface- and ground-water resources (National Park Service, 1999). Water-quality data from key water bodies within the park would add to the record of water-quality data collected in the region. Previous U.S. Geological Survey (USGS) reports have documented results of surface-water-quality analyses in adjacent areas of Spencer County, Indiana, (Renn and others, 1980; Renn, 1983; Zogorski and others, 1981; Silcox and others, 2002) but not within the park. Sites studied by Renn and others (1980) and Silcox and others (2002) (figs. 1 and 2) were near the park. These reports evaluate differences among surface-water-quality data from mined and unmined agricultural and forested lands and document the occurrence of *Escherichia coli* (*E. coli*) bacteria in surface water.

## 2 Reconnaissance, Surface-Water and Ground-Water Quality, Lincoln Boyhood National Memorial



**Figure 1.** Location of the Lincoln Boyhood National Memorial near Lincoln City, Indiana, and selected streams and National Weather Service Cooperative Observer Program weather stations.



EXPLANATION

-  DRAINAGE BASIN DEFINED, USING 14-DIGIT HYDROLOGIC-UNIT BOUNDARIES FROM DEBROKA AND OTHERS (1999)
-  LAKE  
 Lake Lincoln
-  Lincoln City  
 TOWN AREA AND NAME
-  MAJOR ROAD
-  STREAM
-  274 03303400 SURFACE-WATER-QUALITY SITE SAMPLED, WITH 3-DIGIT IDENTIFIER FROM RENN AND OTHERS (1980) OR 8-DIGIT OR 15-DIGIT U.S. GEOLOGICAL SURVEY STATION-IDENTIFICATION NUMBER

NOTE: LOCATION OF STATION NUMBER 03304055 (LITTLE PIGEON CREEK AT STATE ROAD 161 NEAR MIDWAY, INDIANA, ALSO KNOWN AS SITE 35 IN SILCOX AND OTHERS, 2002) IS SHOWN ON FIGURE 1

**Figure 2.** Location of the Lincoln Boyhood National Memorial near Lincoln City, Indiana, and streams and sites closest to the study area that previously were sampled for water quality.

## 4 Reconnaissance, Surface-Water and Ground-Water Quality, Lincoln Boyhood National Memorial

Water-quality data from this study were needed to evaluate whether land uses in and near the park contribute potential contaminants to surface water and ground water of the park. For example, land within 1 mi of the park has been used for exploratory oil and gas drilling and coal exploration and extraction.

The NPS requested the USGS sample and analyze water quality at four surface-water sites and one ground-water site at the Lincoln Boyhood National Memorial near Lincoln City, Indiana. The selected sites were identified by NPS staff, in consultation with USGS staff, as representative of the water bodies within the park.

### Purpose and Scope

This report describes the results of sampling and analysis of surface-water and ground-water quality at selected sites to define baseline water-quality conditions at the park. The sampling and interpretation is required by the Baseline Water Quality Data Inventory and Analysis Program of the NPS, for most park units throughout the Nation (National Park Service, written commun., January 1993). Water-quality information for selected sites within the park, including data to evaluate microbiological quality of the stock pond and the ground water from Lincoln Spring, is provided. The sampling strategy was intended to assist the NPS in identifying potential water-quality-management issues and water-quality-monitoring plans at the park. In addition, the sampling was intended to enable comparison of water quality at sites in the park to standards established by the State of Indiana.

Results of water-quality sampling are compared with State of Indiana standards for contact recreation and aquatic life and with Federal standards for drinking-water quality. Data also are compared between sites sampled for this study and sites sampled by previous studies within and adjacent to Spencer County, Indiana.

Water-quality data were collected during fall, spring, and summer. Brief descriptions of the data collection for each time period follow.

- November 29, 2001—Discharge measurements were made at three surface-water sites. Water samples were collected at four surface-water sites and analyzed for concentrations of selected major ions and trace metals, nutrients, and various water-quality characteristics.
- March 26, 2002—Discharge measurements were made at three surface-water sites. Water samples were collected at four surface-water sites and analyzed for concentrations of selected major ions and trace metals, nutrients, and various water-quality characteristics.
- July 10, 2002—Water samples were collected at one surface-water site (stock pond) and one ground-water site (Lincoln Spring) and analyzed for concentrations of selected major ions and trace metals, nutrients, petroleum hydrocarbons, organic carbon, and various water-quality characteristics, including *E. coli* bacteria.

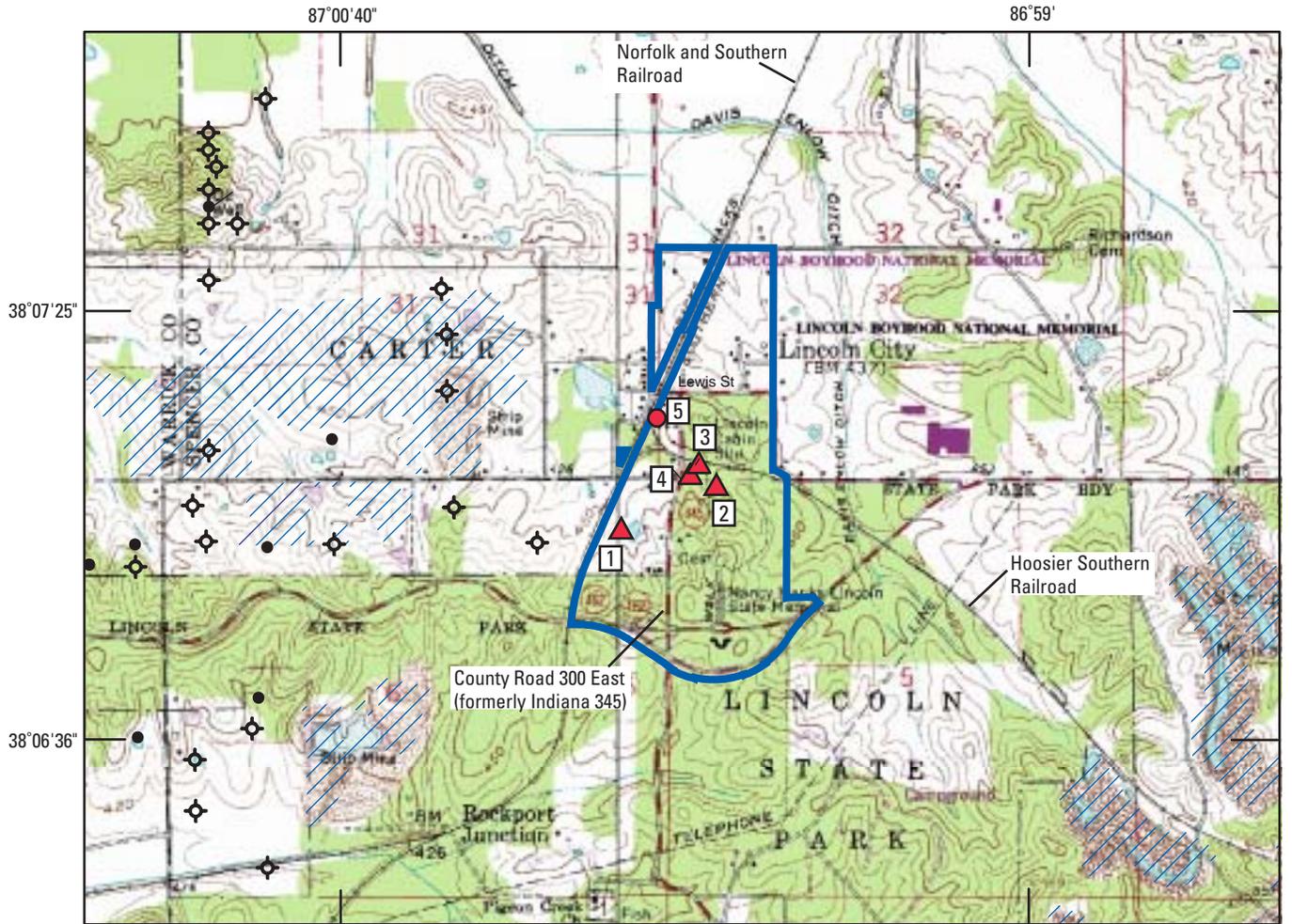
### Physical Setting

The park is east of Lincoln City in the northwestern part of Spencer County in southwestern Indiana (fig. 1). The total park area is about 200 acres; that area drains to tributaries of Little Pigeon Creek (figs. 1 and 2). One of those tributaries is an ephemeral stream, Davis Enlow Ditch, that receives drainage from nearly all the park area. The ditch is about 0.1 mi east of the park's eastern boundary and about 0.3 mi north of the park's northern boundary. The park and ditch are within Little Pigeon Creek–Buckhorn Creek hydrologic unit (14-digit hydrologic-unit number 05140201140030) that has a drainage area of 14,372 acres (DeBroka and others, 1999). A small area south of the Nancy Hanks Lincoln State Memorial (fig. 3) drains southward to a tributary of Buckhorn Creek. Little Pigeon Creek is a tributary of the Ohio River.

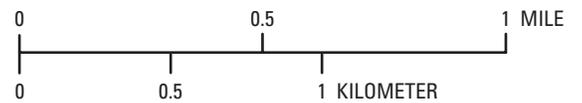
The climate in Indiana is midwestern continental with four distinct seasons that range from hot, humid summers to cold, wet winters. Normal monthly mean temperatures for the period 1971 to 2000 ranged from 0°C in January to 25.6°C in July at a National Weather Service Cooperative Observer Program (NWS-COP) weather station about 16 mi west-southwest from the park near Boonville in Warrick County, Indiana (fig. 1) (National Oceanic and Atmospheric Administration, 2004). Normal monthly mean temperatures from 1971 to 2000 ranged from 0.17°C in January to 24.95°C in July at a NWS-COP weather station about 11 mi east-northeast from the park near Saint Meinrad in Spencer County, Indiana (fig. 1) (Midwestern Regional Climate Center, 2004). Normal precipitation at the Boonville weather station from 1971 to 2000 was about 47.2 in./yr. Monthly mean precipitation at the Boonville weather station during that period ranged from 2.71 in. in September to 4.96 in. in May. Normal precipitation at the Saint Meinrad weather station from 1971 to 2000 was about 46.6 in./yr. Monthly mean precipitation at the Saint Meinrad weather station during that period ranged from 2.88 in. in October to 4.75 in. in May.

The park is within the Wabash Lowland physiographic region (Malott, 1922). Land-surface altitudes in the park range from about 520 ft above NGVD 29 at the Nancy Hanks Lincoln State Memorial (fig. 3) to about 420 ft at the northwestern corner of the park adjacent to the Norfolk and Southern Railroad.

The park is underlain primarily by sandstone and shale of Pennsylvanian age and is situated south of the Illinoian and Wisconsinan glacial boundaries (Woodfield and Fenelon, 1994). Much of the area is covered by a thin veneer, about 10 ft in thickness, of unconsolidated surficial deposits representative of the western unglaciated part of the Ohio River Basin (Woodfield and Fenelon, 1994). Bedrock underlying the area consists of a complexly interbedded sandstone, shale, and limestone of the Raccoon Creek Group (Gray and others, 1970). The Buffaloville Coal Member of the Brazil Formation, Raccoon Creek Group is at or near the land surface to the west and south of the park and possibly in the park (Gray and others, 1970).



Base from U.S. Geological Survey Digital Raster Graphic 1:24,000; Chrisney, 1960, photorevised 1988; Dale, 1961, photorevised 1980; Holland, 1961, photorevised 1980; Santa Claus, 1960, photorevised 1980; Universal Transverse Mercator projection, Zone 16, North American Datum 1927, National Geodetic Vertical Datum 1929



EXPLANATION

-  FORMER SURFACE COAL MINE
-  LINCOLN BOYHOOD NATIONAL MEMORIAL BOUNDARY
-  SURFACE-WATER-QUALITY MEASUREMENT SITE WITH SITE IDENTIFIER
-  GROUND-WATER-QUALITY MEASUREMENT SITE WITH SITE IDENTIFIER
-  OIL- AND GAS-EXPLORATION WELL
-  OIL- OR GAS-PRODUCTION WELL

**Figure 3.** Locations of sampling sites, oil- and gas-exploration wells, and former surface coal mines near the Lincoln Boyhood National Memorial near Lincoln City, Indiana.

The shallow aquifer in the area is in bedrock of the Raccoon Creek Group and is referred to by Woodfield and Fenelon (1994, p. 185) as the “complexly interbedded sandstone, shale, limestone, and coal aquifer.” The aquifer is described as poorly productive and a secondary source of water (Woodfield and Fenelon, 1994). Most wells in this aquifer yield about 20 gal/min or less, with yields commonly less than about 2 gal/min.

Two general soil types predominate in the park area (Williamson and Shively, 1973, map sheet 10). Zanesville silt loam soils predominate on sandstone and shale uplands. These soils are characterized by medium-term to rapid runoff, especially where slopes are most severe. Tilsit series soils predominate in the central part of the park and consist of deep, moderately well-drained, medium-textured, gently sloping to nearly level soils. Runoff is slow from this soil association. Stendal silt loam is deposited in the channel of one swale that crosses the northern-most part of the park.

### Lincoln Boyhood National Memorial Land Use and Park History

Land uses in the park include forest, cultivated agriculture, and pasture. The cultivated-agriculture areas within the park are part of a primitive farm that is used for agricultural demonstrations related to livestock-grazing and subsistence-farming practices of the early 1800s. All other land is devoted to trail, road, parking lot, railroad corridors, memorial areas, or support buildings.

Outside the park, land uses principally include cultivated agriculture, pasture, forest, residential, and transportation (railroad and road) areas. Land about 0.3 mi east and about 0.75 mi west of the park was mined for coal with surface-mining methods (fig. 3). In that same area, oil- and gas-exploration wells have been drilled; several were completed and are oil- and gas-production wells (fig. 3).

Major features of the park include the Living Historical Farm, the Memorial Visitor Center, and Lincoln Spring (fig. 4). The Living Historical Farm is a re-created 1820s pioneer homestead on 4 acres. The farm includes demonstrations of farm life from that period, including livestock raising, cultivation of field and garden crops, and home life. A pasture with a stock pond lies within the park and is used by livestock.

The Memorial Visitor Center represents an expression of the Nation's respect and reverence for Abraham Lincoln. Lincoln's mother, Nancy Hanks Lincoln, is buried at the park. The Nancy Hanks Lincoln Memorial was under the administration of the State of Indiana from its creation until 1962 when Congress established the Lincoln Boyhood National Memorial. The park was the first national park unit created within Indiana.

Lincoln Spring was the main source of fresh water for the Lincoln family. It is attributed as one of the reasons that the Lincoln family located their homestead at this site.

## Methods of Study

Study activities included selection of sites in the park to assess water quality, selection of analytical methods, and field activities associated with the data collection. Surface-water- and ground-water-data collection included measurement of stream discharge and water-quality characteristics. Water-quality samples were collected for analysis of selected major ions, nutrients and trace metals, organic carbon, petroleum hydrocarbons, suspended sediment, and *E. coli*.

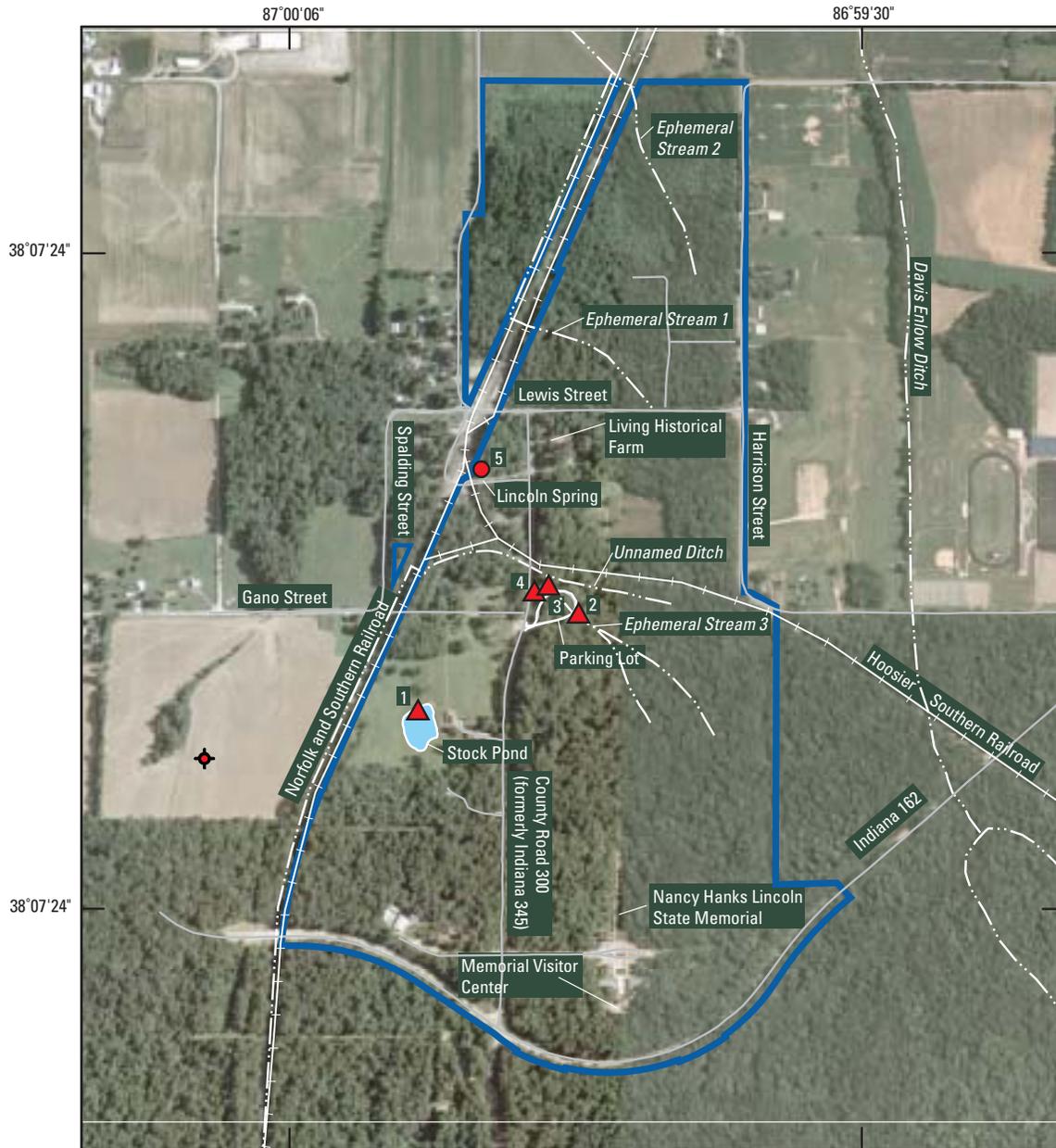
### Site Selection

An NPS Level 1 water-quality inventory involves a sampling of key water bodies in a park. Key water bodies in the park were defined in discussions by USGS project staff with NPS natural resource management staff (Michael Capps and Gia Wagner, National Park Service, oral commun., February 2001), and an NPS hydrologist (Gary Rosenlieb, National Park Service, oral commun., February 2001). The water resources within the park that are included in the water-quality inventory are described below and in table 1; these sites are shown in figures 3 and 4.

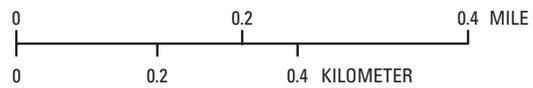
**Site 1, stock pond.** A stock pond, the only perennial surface-water body in the study area, is surrounded by fenced pasture and is in an area used for park maintenance. The pond is not accessed by visitors. The stock pond has no apparent inflows other than storm runoff from surrounding lands, precipitation, and possibly ground-water discharge. Fewer than 10 head of livestock (cattle, horses, or sheep) use the pasture at any time. This site (figs. 3 and 4) was selected for sampling because it represents possible nonpoint agricultural effects on water quality.

**Site 2, ephemeral stream 3.** Three ephemeral streams were identified in the park. Each of the ephemeral streams is considered a first-order stream, according to the classification system described by Chow and others (1988). First-order streams are the smallest recognizable channels in a watershed and flow only during periods of wet weather. Theoretically, similarly ordered streams have similar hydraulic properties and ecological function (Graves, 2001, p. 9).

Ephemeral stream 1 is in a swale that begins north of Lewis Street (fig. 4) and extends west-northwest out of the park; the swale then passes through a culvert and under the railroad tracks. Ephemeral stream 2 is in another swale that begins north of Lewis Street and extends north-northwest out of the park. Both streams receive flow from forested areas in the park. Ephemeral stream 3 extends from the forested area north of the Nancy Hanks Lincoln Memorial site northward to a parking lot on the east side of County Road 300 East. The stream then flows under the parking lot through a culvert and emerges on the north side of the parking lot. This site (fig. 4) was selected to represent the water quality of drainage from forested and memorial areas of the park.



Base from U.S. Department of Agriculture Digital Orthophotography, Leaf on, 1-meter ground resolution, Universal Transverse Mercator, Zone 16, North American Datum 1983. Imagery collected between April and September 2002



EXPLANATION

- |   |  |   |   |
|---|--|---|---|
|  | LINCOLN BOYHOOD NATIONAL MEMORIAL BOUNDARY                   |  | OIL- AND GAS-EXPLORATION WELL                                 |
|  | STREAM (black symbols here shown in white on figure)         |  | 3 SURFACE-WATER-QUALITY MEASUREMENT SITE WITH SITE IDENTIFIER |
|  | RAILROAD GRADE (black symbols here shown in white on figure) |  | 5 GROUND-WATER-QUALITY MEASUREMENT SITE WITH SITE IDENTIFIER  |
|  | POND   |   |   |

Figure 4. Orthophoto showing sampling sites in and near the Lincoln Boyhood National Memorial near Lincoln City, Indiana.

## 8 Reconnaissance, Surface-Water and Ground-Water Quality, Lincoln Boyhood National Memorial

**Table 1.** Description and purpose of sampling for key water bodies at the Lincoln Boyhood National Memorial near Lincoln City, Indiana, 2001–02 (sites shown in fig. 3).

[USGS, U.S. Geological Survey]

USGS station-identification number	Site name and local number	Site type	Purpose of sampling	Sampling season and date collected
380701086595801	Stock pond (site 1)	Perennial pond	Possible nonpoint agricultural effects	Fall precipitation (November 29, 2001). Spring precipitation (March 26, 2002). Summer precipitation (July 10, 2002).
380706086594801	Ephemeral stream 3 (site 2)	First-order stream (ephemeral)	Water quality of drainage from forested and memorial areas	Fall precipitation (November 29, 2001). Spring precipitation (March 26, 2002) <sup>1</sup> .
380707086595001	Parking-lot runoff (site 3)	Parking-lot runoff (ephemeral)	Water quality related to road and parking-lot runoff	Fall precipitation (November 29, 2001). Spring precipitation (March 26, 2002) <sup>1</sup> .
380707086595101	Unnamed ditch (site 4)	Second-order stream (ephemeral)	Water quality of parking-lot runoff and area adjacent to railroad	Fall precipitation (November 29, 2001). Spring precipitation (March 26, 2002) <sup>1</sup> .
380714086595501	Lincoln Spring (site 5)	Ground water/spring	Ground-water conditions near a former diesel-fuel spill	Summer precipitation (July 10, 2002).

<sup>1</sup>Collection of a third sample was attempted on July 10, 2002, but precipitation was insufficient to cause sustained flow in ephemeral stream 3, in parking-lot runoff, or in the unnamed ditch.

**Site 3, parking-lot runoff.** Drainage from the parking lot along County Road 300 East is directed underground by various storm grates that lead into ephemeral stream 3 as it flows through the culvert beneath the parking lot. The ephemeral stream empties into a ditch that flows along the right-of-way of the Hoosier Southern Railroad tracks that cross the park. This site (figs. 3 and 4) was sampled to represent water quality related to road and parking-lot runoff.

**Site 4, unnamed ditch.** A ditch along the south side of the railroad tracks that cross the park is classified as a second-order stream because it receives drainage from ephemeral stream 3. Drainage from the parking lot above the ditch and from ephemeral stream 3 flows into the ditch. Because of the potential contribution of runoff from the parking lot and from the Hoosier Southern Railroad right-of-way, the ditch was sampled below its confluence with ephemeral stream 3. The site (figs. 3 and 4) represents the effects on water quality of parking-lot runoff and drainage from an area adjacent to a railroad track.

**Site 5, Lincoln Spring.** Lincoln Spring is a ground-water fed, rock-masonry well next to railroad tracks along the north-west park boundary. The source of water to Lincoln Spring is probably from the Raccoon Creek Group. The Raccoon Creek Group is an interbedded sandstone, shale, and limestone complex of the Pennsylvanian age and is the shallow aquifer in the area. Water from Lincoln Spring was used by some local residents until about 1966 when rural water service was extended to Lincoln City and the park (D Brown, National Park Service, oral commun., July 10, 2002). The spring is thought to contain

water year round. This site (figs. 3 and 4) represents localized ground-water conditions near a former diesel-fuel spill.

In December 1995, a leak of diesel fuel from a parked locomotive onto property adjacent to Lincoln Spring was reported (D Brown, National Park Service, oral commun., July 10, 2002). Soil and ground water were affected. The spill was remediated by removing the railroad tracks, excavating the contaminated soil and replacing it with clean fill, installing a geofabric pad, and reinstalling the railroad tracks. Lincoln Spring was used to pump contaminated ground water from the shallow aquifer until remediation goals were met (Indiana Department of Environmental Management, written commun., January 1996). Lincoln Spring was covered with a large capstone at the end of the spill remediation. The capstone was removed with straps and a forklift by park personnel when the site was sampled by the USGS.

### Water-Quality Sampling

Because the presence of water at three of the four surface-water-sampling sites is ephemeral, sampling trips were scheduled and coordinated based on National Weather Service radar imagery and conversations with park personnel. A sampling trip consisted of two personnel driving from the USGS Indiana Water Science Center in Indianapolis, approximately 157 mi southwest to the park. Driving time was about 3 hours

and 30 minutes. If precipitation was insufficient to cause sustained flow at the time of the USGS sampling visit, no sample was collected. According to data from the closest USGS streamflow-gaging station, number 03303400, Crooked Creek near Santa Claus, Indiana (fig. 2), the wettest periods are in the spring; however, there can be appreciable streamflow during other times of the year (Stewart and others, 2003). The sites sampled, the purpose of the sampling, and the dates of the sampling are listed in table 1.

## Selection of Sampling Constituents

The NPS identified basic water-quality characteristics and constituents that all national parks must analyze for in key water bodies in park boundaries (National Park Service, 1993). Results of the water-quality analyses are compared where appropriate with water-quality standards for aquatic life, drinking water, and recreational contact. The results also are compared with local water-quality data to identify potential differences and emerging issues that could affect the use of water resources within the park.

Water samples were analyzed for dissolved oxygen and pH and selected major ions, trace metals, and nutrients. Various

optional water-quality characteristics (table 2) and constituents also were selected for analysis. This information provided water-quality data and allowed for a comparison with State of Indiana standards. The evaluation of water quality from the stock pond and Lincoln Spring required the measurement of the indicator bacteria *E. coli* in samples from those sites. To evaluate water quality relative to potential residual contamination from parking-lot runoff and from the fuel spill near Lincoln Spring, selected water samples were analyzed for organic carbon and petroleum hydrocarbons. The analytical constituents sampled and the analytical methods used are listed in table 3 (back of report).

## Collection and Analysis of Water-Quality Samples

Surface-water samples were collected from the stock pond by USGS personnel in a boat. Depth to the pond bottom was measured with a weighted tape, and the midpoint between the water surface and pond bottom was determined. A polytetrafluoroethylene (PTFE) hose connected to a peristaltic pump was lowered to the middle depth of the pond with a pole.

**Table 2.** National Park Service, Water Quality Inventory and Monitoring Program, Level 1, required and optional characteristics.

[-- , no remark]

Water-quality characteristics for Level 1 sampling	Required or optional groups	Sampled for this study	Remarks
Alkalinity	Required	Yes	Values reported as concentrations of calcium carbonate.
pH	Required	Yes	--
Specific conductance	Required	Yes	--
Dissolved oxygen	Required	Yes	--
Rapid bioassessment baseline (fish and macroinvertebrates)	Required	No	Surface-water flows were too ephemeral to consider for sampling.
Water temperature	Required	Yes	--
Streamflow	Required	Yes	--
Trace metals	Optional	Yes	--
Turbidity (clarity) or suspended sediment	Optional	Yes	--
Nitrate, as nitrogen	Optional	Yes	--
Phosphorus, total	Optional	Yes	--
Chlorophyll	Optional	No	--
Sulfate	Optional	Yes	--
Bacteria ( <i>Escherichia coli</i> )	Optional	Yes	Sampled in July 2002 at stock pond and Lincoln Spring only because of lack of flow at other sites.

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Surface-water samples from ephemeral stream 3, the unnamed ditch, and parking-lot runoff were collected with a pump because the streamflow at each sampling point was less than 0.25 ft<sup>3</sup>/s; this nonisokinetic technique provided a well-mixed sample with minimal disturbance of the streambed sediment. When flowing, water depths at the sampling sites of the ephemeral stream, the unnamed ditch, and the parking-lot runoff were less than 1 ft and were too small to apply equal-depth increment or equal-width increment techniques. For field-parameter measurement and sample collection, a site was selected where the streamflow appeared to integrate water from the full width and depth of the stream (or flowing water in the parking lot). A PTFE hose was fixed in the horizontal and vertical center of flow and connected to a peristaltic pump on a platform on the streambank. Another PTFE hose was connected to the outlet of the pump and fixed to a portable lab stand. The PTFE hose was flushed with stream water before the samples were collected. Unfiltered samples were collected first. Next, the hose was connected to a 0.45- $\mu$ m pore-size capsule filter, and the filtered samples were collected.

Using procedures consistent with the USGS Field Manual for the Collection of Water-Quality Data (Wilde and Radtke, variously dated), pH, specific conductance, water temperature, and dissolved oxygen were measured with an electrometric multimeter. Turbidity samples were measured with a portable nephelometric turbidimeter. Criteria for stabilization of the four characteristics in ground-water samples were  $\pm 0.2$  standard units pH,  $\pm 0.2^\circ\text{C}$  water temperature,  $\pm 10$   $\mu\text{S}/\text{cm}$  specific conductance, and  $\pm 5$  nephelometric turbidity units.

The amount of water transported in a stream can affect water quality and contaminant transport. In this report, streamflow was used to describe the volume flow rate of water in cubic feet per second (ft<sup>3</sup>/s). Instantaneous streamflow was reported because continuous-record streamflow-gaging stations were not in the study area. Measurements were made, using a current meter and methods described in Rantz and others (1982), Carter and Davidian (1968), Buchanan and Somers (1969), and Smoot and Novak (1968). Streamflow was measured at a stream cross section at or near the water-sampling site immediately after sampling was completed.

To collect the ground-water sample from Lincoln Spring, a submersible, positive-displacement pump was placed near the bottom of the well during purging and sampling. The well was pumped for about 2 hours about 1 month before sampling to purge stagnant water; it was pumped again on the day of sampling for about 1 hour to obtain samples representative of water in the aquifer. Water temperature, pH, and specific conductance were monitored during pumping until the values stabilized. The sampling pump and hose were cleaned before the well was sampled. Procedures followed were (a) the external surfaces of the pump and hose that were submerged during sampling were rinsed with a deionized (DI) water spray, (b) about 5 gal of a

dilute solution of phosphate-free detergent and DI water were recirculated through the pump and hose for about 3 to 5 minutes, and (c) about 10 gal of DI water were pumped through the hose.

Samples for chemical analysis were preserved in the field, chilled, and shipped on ice by overnight freight to the USGS National Water Quality Laboratory in Denver, Colorado. Water samples were analyzed with the methods listed in table 3 (back of report) for various water-quality characteristics and selected major ions, trace metals, and nutrients and for petroleum hydrocarbons and organic carbon. Samples for suspended-sediment analysis were shipped to the USGS Sediment Laboratory in Louisville, Kentucky.

### Collection and Analysis of *Escherichia coli* Samples

Analysis of water samples determined the concentrations of *E. coli* bacteria. Methods were consistent with those of Silcox and others (2002) used throughout the Ohio River Basin in Indiana in a cooperative assessment of water quality with IDEM.

Water samples were collected in 300-mL glass bottles. Before use, all sample-processing equipment was washed and sterilized with an ultraviolet lamp that had a wavelength of 254 nanometers. Membrane filters, sterile buffer solution, sterile dilution water, and petri dishes were quality assured by the USGS Quality of Water Services Unit in Ocala, Florida. Agar media kits were quality assured by the USGS Ohio Water Science Center Microbiology Laboratory in Columbus, Ohio. Samples were kept on ice until processed.

All of the sample processing and analysis was done by USGS Indiana Water Science Center personnel within 6 hours or less of sample collection, according to methods in Myers and Wilde (2003). Sample processing involved filtering the water, plating the filters on growth media, and incubating the filter plates. Six to eight different sample volumes, including one to three different dilutions, were filtered for each site because the number of possible *E. coli* colony-forming units was unknown. This approach was intended to produce at least one sample with an *E. coli* colony count in the ideal range of 20 to 80 colonies per filter plate.

Sample dilutions were made with sterile water. Sterile, disposable, glass pipets or graduated cylinders were used to measure and deliver a concentrated sample volume to dilution bottles. A stainless-steel filter-funnel system attached to a vacuum pump was used to process the sample volume through a 0.45- $\mu$ m pore-size filter designed to capture *E. coli* for incubation and quantification. After the sample was filtered, sterile saline buffer solution was used to rinse the graduated cylinder and filter funnel, and the rinseate was filtered. Fresh, membrane-filter thermotolerant agar in labelled petri dishes was used to encourage growth of *E. coli* colonies on the prepared filters. The filter plates were placed for 2 hours in a pre-heated incubator set at 35.0°C and then moved to another pre-heated incubator for 22 to 24 hours set at 44.5°C.

Analysis involved counting the *E. coli* colonies on each filter plate and calculating the bacteria concentration for each site. After the second incubation, the filter was transferred to a filter pad saturated with urea/phenol red reagent. After 15 minutes at room temperature, the yellow to yellow-brown *E. coli* colonies were counted under a microscope. If the colony count on the filter plate was in the ideal range, verification was made by recounting the colonies. *E. coli* concentrations were reported as the number of colonies per 100 mL (col/100 mL), using one of three methods: (a) If a colony count on a single filter plate was in the ideal range, the concentration was calculated as the colony count multiplied by 100, and the product divided by the sample volume. (b) If colony counts of multiple filter plates were in the ideal range, the counts were summed, multiplied by 100, and the product divided by the sum of the sample volumes. (c) If there were no colony counts in the ideal range on the filter plates, the concentration was calculated in a manner similar to method (b) with all the filter plates that had colonies; the result was qualified as an estimate.

## Quality Assurance

Field quality-assurance components included multimeter calibration, turbidimeter-operation checks, equipment cleaning between sampling sites, sample-custody documentation, and field quality-control samples. Laboratory quality-assurance components included control samples to assess analytical accuracy; duplicates to assess analytical precision, bias, and sample representativeness; and blanks to assess possible contamination.

Before use each sampling day, the electrometric multimeter was calibrated, using laboratory-grade calibration solutions and following manufacturer's procedures and methods in the USGS Field Manual for the Collection of Water-Quality Data (Wilde and Radtke, variously dated). Performance of the portable nephelometric turbidimeter was checked daily, using standard cells and following manufacturer's procedures and methods in the USGS Field Manual for the Collection of Water-Quality Data (Anderson, 1998). Water-sampling equipment was cleaned by pumping a dilute solution of phosphate-free detergent followed by two deionized-water rinses.

Field quality assurance also was implemented for the chemical analysis of water samples. Field quality-control samples included sequential duplicates and equipment blanks. Sequential duplicate samples were used to assess the precision of laboratory analytical data. A sequential duplicate is a sample collected in close succession to the water sample (referred to here as the water-quality sample) from the same water source, using the same equipment and methods. Sequential duplicates were submitted to NWQL with water-quality samples for identical analyses. The relative percent difference (RPD) is the absolute value of the difference of the two concentrations divided by the average of the sum of the concentrations,

expressed as a percent. The RPDs were computed for the paired water-quality and sequential duplicate samples as

$$RPD = |(SDS - WQS) / ((SDS + WQS) / 2)| \times 100, \quad (1)$$

where

- RPD* is the relative percent difference,
- SDS* is the concentration in the sequential duplicate sample, and
- WQS* is the concentration in the water-quality sample.

This statistic is used to summarize the RPD in concentrations between two samples that should be identical in composition and that were identical in their handling and analysis. If the RPD of paired water-quality and sequential duplicate samples was within 25 percent, the collected data were determined to meet the precision objectives of the project. If the RPD of paired water-quality and sequential duplicate samples was greater than 25 percent, the collected data were reported but were flagged with a code letter "Q" in the data (table 4) to indicate that the sample concentration is estimated.

Equipment blank samples were collected and analyzed to determine whether the water samples were being contaminated by the sampling equipment or by residue from previous samples. Equipment blank samples were prepared by pumping either deionized water or organic-free water through the sampling apparatus after the pre-sampling cleaning protocol. Deionized water was used to prepare the equipment blank sample for analyses of major ions, nutrients, and trace metals; reagent-grade organic-free water was used to prepare equipment blank samples for analysis of organic constituents.

Concentrations of constituents in equipment blank samples were compared with the analytical results from the water-quality samples to assess whether sample-collection interferences were present. These classifications were

1. No apparent interference; constituent not detected in equipment blank or not detected in a subsequent water-quality sample.
2. No apparent interference; constituent concentration in a subsequent water-quality sample is more than two times the concentration detected in equipment blank.
3. Potential interference; constituent concentration in a subsequent water-quality sample is within two times the concentration detected in equipment blank.

For quality assurance of samples collected for *E. coli* analysis, two filter blanks, one process blank, one field blank, and a sequential duplicate sample were prepared and analyzed during the one *E. coli* sampling done for this study. Analysis of these quality-control samples provided quantitative information about the potential for sample contamination during collection and processing and limited information about the variability of the samples. A filter blank was processed before each set of samples to determine if the processing equipment was clean and the saline buffer solution was sterile. A process blank was

**Table 4.** Surface-water- and ground-water-quality data from sites at the Lincoln Boyhood National Memorial near Lincoln City, Indiana, 2001–02.

[USGS, U.S. Geological Survey; mm/dd/yyyy, month/day/year; hhmm, hours and minutes; ft<sup>3</sup>/s, cubic foot per second; NTU, nephelometric turbidity unit; mg/L, milligram per liter;  $\mu$ S/cm, microsiemen per centimeter; °C, degree Celsius; *E. coli*, *Escherichia coli*; mL, milliliter; --, not measured or determined; K, non-ideal colony count; <, less than; CaCO<sub>3</sub>, calcium carbonate; SiO<sub>2</sub>, silica; N, nitrogen; P, phosphorus; E, Estimated value;  $\mu$ g/L, microgram per liter; V, concentration within two times the value determined in a corresponding equipment blank sample; M, presence verified but not quantified; Q, sample concentration estimated because relative percent difference of environmental and sequential duplicate samples was greater than 25 percent; all concentrations reported are as dissolved constituents, except when noted]

USGS station-identification number	Site number	Site name	Date sampled (mm/dd/yyyy)	Time sampled (hhmm)	Discharge (ft <sup>3</sup> /s)	Turbidity (NTU)	Dissolved oxygen (mg/L)	pH, field (standard units)	Specific conductance ( $\mu$ S/cm)	Water temperature (°C)	<i>E. coli</i> bacteria, (colonies/100 mL)
380701086595801	1	Stock pond	11/29/2001	1645	--	28	8.2	7.5	94	9.3	--
380701086595801	1	Stock pond	03/26/2002	1730	--	43	11.8	7.3	131	7.3	--
380701086595801	1	Stock pond	07/10/2002	1030	--	22	4.8	6.9	133	29.5	K11
380706086594801	2	Ephemeral stream 3	11/29/2001	1530	.21	13	9.2	6.2	83	10.7	--
380706086594801	2	Ephemeral stream 3	03/26/2002	1620	.21	16	10.9	6.5	121	6.0	--
380707086595001	3	Parking-lot runoff	11/29/2001	1300	.08	19	5.4	7.2	129	10.3	--
380707086595001	3	Parking-lot runoff	03/26/2002	1230	.01	20	10.1	7.9	157	6.6	--
380707086595101	4	Unnamed ditch	11/29/2001	1430	.21	25	8.2	7.0	172	10.6	--
380707086595101	4	Unnamed ditch	03/26/2002	1445	.20	26	10.3	7.1	157	6.4	--
380714086595501	5	Lincoln Spring	07/10/2002	1300	--	.7	<.1	5.9	837	19.6	K3

**Table 4.** Surface-water- and ground-water-quality data from sites at the Lincoln Boyhood National Memorial near Lincoln City, Indiana, 2001–02.—Continued

[USGS, U.S. Geological Survey; mm/dd/yyyy, month/day/year; hhmm, hours and minutes; ft<sup>3</sup>/s, cubic foot per second; NTU, nephelometric turbidity unit; mg/L, milligram per liter;  $\infty$ S/cm, microsiemen per centimeter; °C, degree Celsius; *E. coli*, *Escherichia coli*; mL, milliliter; --, not measured or determined; K, non-ideal colony count; <, less than; CaCO<sub>3</sub>, calcium carbonate; SiO<sub>2</sub>, silica; N, nitrogen; P, phosphorus; E, Estimated value;  $\infty$ g/L, microgram per liter; V, concentration within two times the value determined in a corresponding equipment blank sample; M, presence verified but not quantified; Q, sample concentration estimated because relative percent difference of environmental and sequential duplicate samples was greater than 25 percent; all concentrations reported are as dissolved constituents, except when noted]

USGS station-identification number	Site name	Date sampled (mm/dd/yyyy)	Time sampled (hhmm)	Hardness, dissolved (mg/L as CaCO <sub>3</sub> )	Calcium, dissolved (mg/L)	Magnesium, dissolved (mg/L)	Potassium, dissolved (mg/L)	Sodium, dissolved (mg/L)	Alkalinity (mg/L as CaCO <sub>3</sub> )	Chloride, dissolved (mg/L)
380701086595801	Stock pond	11/29/2001	1645	35	8.74	3.17	2.73	1.61	18	2.5
380701086595801	Stock pond	03/26/2002	1730	44	10.5	4.33	1.71	3.7	15	4.09
380701086595801	Stock pond	07/10/2002	1030	51	11.7	5.27	3.23	3.76	42	2.81
380706086594801	Ephemeral stream 3	11/29/2001	1530	39	10.5	3.11	2.02	1.69	15	1.34
380706086594801	Ephemeral stream 3	03/26/2002	1620	47	12.3	4.04	.96	2.86	16	1.17
380707086595001	Parking-lot runoff	11/29/2001	1300	70	21.4	4.03	2.27	1.12	52	1.86
380707086595001	Parking-lot runoff	03/26/2002	1230	83	26.2	4.27	1.42	1.65	63	1.22
380707086595101	Unnamed ditch	11/29/2001	1430	86	25.7	5.22	2.61	1.62	69	2.06
380707086595101	Unnamed ditch	03/26/2002	1445	67	19.8	4.35	1.36	2.12	52	1.59
380714086595501	Lincoln Spring	07/10/2002	1300	290	71.3	27.6	8.75	48.2	5	128

**Table 4.** Surface-water- and ground-water-quality data from sites at the Lincoln Boyhood National Memorial near Lincoln City, Indiana, 2001–02.—Continued

[USGS, U.S. Geological Survey; mm/dd/yyyy, month/day/year; hhmm, hours and minutes; ft<sup>3</sup>/s, cubic foot per second; NTU, nephelometric turbidity unit; mg/L, milligram per liter;  $\mu$ S/cm, microsiemen per centimeter; °C, degree Celsius; *E. coli*, *Escherichia coli*; mL, milliliter; --, not measured or determined; K, non-ideal colony count; <, less than; CaCO<sub>3</sub>, calcium carbonate; SiO<sub>2</sub>, silica; N, nitrogen; P, phosphorus; E, Estimated value;  $\mu$ g/L, microgram per liter; V, concentration within two times the value determined in a corresponding equipment blank sample; M, presence verified but not quantified; Q, sample concentration estimated because relative percent difference of environmental and sequential duplicate samples was greater than 25 percent; all concentrations reported are as dissolved constituents, except when noted]

USGS station-identification number	Site name	Date sampled (mm/dd/yyyy)	Time sampled (hhmm)	Fluoride, dissolved (mg/L)	Silica, dissolved (mg/L as SiO <sub>2</sub> )	Sulfate, dissolved (mg/L)	Ammonia, dissolved (mg/L as N)	Nitrite plus nitrate, dissolved (mg/L as N)	Nitrite, dissolved (mg/L as N)	Phosphorus, total (mg/L as P)
380701086595801	Stock pond	11/29/2001	1645	<0.1	7.7	19.4	--	0.25	E0.004	0.08
380701086595801	Stock pond	03/26/2002	1730	E.1	8.0	32.6	.04	.24	E.005	.07
380701086595801	Stock pond	07/10/2002	1030	.2	7.4	16.5	.01	E.02	<.008	.08
380706086594801	Ephemeral stream 3	11/29/2001	1530	<.1	11.6	26.4	--	1.25	<.008	<.06
380706086594801	Ephemeral stream 3	03/26/2002	1620	E.1	12.2	33.9	.01	.98	<.008	<.06
380707086595001	Parking-lot runoff	11/29/2001	1300	E.1	10.8	18.0	--	<.05	<.008	E.06
380707086595001	Parking-lot runoff	03/26/2002	1230	.1	9.7	19.1	<.01	.08	E.006	E.05
380707086595101	Unnamed ditch	11/29/2001	1430	E.1	11.9	21.8	--	.05	<.008	.06
380707086595101	Unnamed ditch	03/26/2002	1445	.1	11.0	20.8	.01	.09	<.008	E.05
380714086595501	Lincoln Spring	07/10/2002	1300	.1	24.8	156	--	16.5	<.08	<.06

**Table 4.** Surface-water- and ground-water-quality data from sites at the Lincoln Boyhood National Memorial near Lincoln City, Indiana, 2001–02.—Continued

[USGS, U.S. Geological Survey; mm/dd/yyyy, month/day/year; hhmm, hours and minutes; ft<sup>3</sup>/s, cubic foot per second; NTU, nephelometric turbidity unit; mg/L, milligram per liter;  $\mu$ S/cm, microsiemen per centimeter; °C, degree Celsius; *E. coli*, *Escherichia coli*; mL, milliliter; --, not measured or determined; K, non-ideal colony count; <, less than; CaCO<sub>3</sub>, calcium carbonate; SiO<sub>2</sub>, silica; N, nitrogen; P, phosphorus; E, Estimated value;  $\mu$ g/L, microgram per liter; V, concentration within two times the value determined in a corresponding equipment blank sample; M, presence verified but not quantified; Q, sample concentration estimated because relative percent difference of environmental and sequential duplicate samples was greater than 25 percent; all concentrations reported are as dissolved constituents, except when noted]

USGS station-identification number	Site name	Date sampled (mm/dd/yyyy)	Time sampled (hhmm)	Arsenic, total ( $\mu$ g/L)	Cadmium, total ( $\mu$ g/L)	Chromium, total ( $\mu$ g/L)	Copper, total ( $\mu$ g/L)	Iron, dissolved ( $\mu$ g/L)	Lead, total ( $\mu$ g/L)	Manganese, dissolved ( $\mu$ g/L)
380701086595801	Stock pond	11/29/2001	1645	E1	0.4	E0.5	V2	178	1	64.7
380701086595801	Stock pond	03/26/2002	1730	<2	.4	E.7	E1.1	226	2	251
380701086595801	Stock pond	07/10/2002	1030	5	<.1	<.8	E.8	142	M	371
380706086594801	Ephemeral stream 3	11/29/2001	1530	E1	<.1	E.5	V1.8	145	M	18.1
380706086594801	Ephemeral stream 3	03/26/2002	1620	<2	<.1	<.8	E.7	99	M	33
380707086595001	Parking-lot runoff	11/29/2001	1300	E1	<.1	<.8	V2.2	221	5	6.6
380707086595001	Parking-lot runoff	03/26/2002	1230	<2	<.1	E.5	1.2	150	3	3.8
380707086595101	Unnamed ditch	11/29/2001	1430	E1	<.1	<.8	V2.4	196	7	8.1
380707086595101	Unnamed ditch	03/26/2002	1445	<2	<.1	E.5	1.2	128	6	13.9
380714086595501	Lincoln Spring	07/10/2002	1300	<2	E.1	<.8	11.2	25	1	322

**Table 4.** Surface-water- and ground-water-quality data from sites at the Lincoln Boyhood National Memorial near Lincoln City, Indiana, 2001–02.—Continued

[USGS, U.S. Geological Survey; mm/dd/yyyy, month/day/year; hhmm, hours and minutes; ft<sup>3</sup>/s, cubic foot per second; NTU, nephelometric turbidity unit; mg/L, milligram per liter;  $\mu$ S/cm, microsiemen per centimeter; °C, degree Celsius; *E. coli*, *Escherichia coli*; mL, milliliter; --, not measured or determined; K, non-ideal colony count; <, less than; CaCO<sub>3</sub>, calcium carbonate; SiO<sub>2</sub>, silica; N, nitrogen; P, phosphorus; E, Estimated value;  $\mu$ g/L, microgram per liter; V, concentration within two times the value determined in a corresponding equipment blank sample; M, presence verified but not quantified; Q, sample concentration estimated because relative percent difference of environmental and sequential duplicate samples was greater than 25 percent; all concentrations reported are as dissolved constituents, except when noted]

USGS station-identification number	Site name	Date sampled (mm/dd/yyyy)	Time sampled (hhmm)	Nickel, total ( $\mu$ g/L)	Selenium, total ( $\mu$ g/L)	Silver, total ( $\mu$ g/L)	Zinc, total ( $\mu$ g/L)	Petroleum hydrocarbons, total (mg/L)	Organic carbon, total (mg/L)	Suspended sediment, total (mg/L)
380701086595801	Stock pond	11/29/2001	1645	--	<2	--	<20	2	10.1	22
380701086595801	Stock pond	03/26/2002	1730	<70	<2	<7	E30	<2	6.4	30
380701086595801	Stock pond	07/10/2002	1030	<70	<2	<7	<20	<2	12.2	16
380706086594801	Ephemeral stream 3	11/29/2001	1530	--	<2	--	<20	<2	8.4	17
380706086594801	Ephemeral stream 3	03/26/2002	1620	<70	<2	<7	<20	<2	3.6	19
380707086595001	Parking-lot runoff	11/29/2001	1300	--	<2	--	<20	<2	10.6	9.4
380707086595001	Parking-lot runoff	03/26/2002	1230	<70	<2	<7	<20	<2	5.9	7.2
380707086595101	Unnamed ditch	11/29/2001	1430	--	E1	--	<20	<2	10.3	Q32
380707086595101	Unnamed ditch	03/26/2002	1445	<70	<2	<7	<20	<2	5.2	19
380714086595501	Lincoln Spring	07/10/2002	1300	--	<2	--	<20	3	--	.3

prepared after the last sample processed on the sampling day by filtering saline buffer solution through the equipment onto a fresh filter. The process blank was used to determine if the rinses following each sample were adequate. A field blank was prepared by pouring saline buffer solution into a sample bottle; it was kept with the samples collected that day. Analysis of field blanks is intended to determine the sterilization of sample bottles and the potential for contamination during sample transport. At Lincoln Spring, a sequential duplicate sample was collected immediately after the water-quality sample and processed in the same manner as the water-quality sample. The sequential duplicate sample was used to evaluate the precision of the *E. coli* analysis.

## Reconnaissance of Surface-Water and Ground-Water Quality

Streamflow conditions and precipitation information immediately before and during the water-quality sampling are discussed in the following section. Chemical data are presented from analysis and quality assurance of water samples. Data are presented from one sampling of sites for *E. coli* concentrations. Data from samples collected at the park are compared to each other and to data from sites near the park from previously published USGS studies. The chemical and *E. coli* data are discussed with respect to water-quality standards, potential sources of contamination, and uncertainties of interpretation.

### Streamflow and Precipitation Conditions

Because no streamflow-gaging stations are in the park, estimated rainfall amounts shown by Doppler radar from National Weather Service websites (National Oceanic and Atmospheric Administration, 2001 and 2002) were used to evaluate whether streams in the park were flowing sufficiently for sampling. Daily streamflow and precipitation data from area streamflow-gaging stations and observations by NPS staff also were used to identify general streamflow conditions for this study (Stewart and others, 2003; Fowler and Wilson, 1996). The streams in the park are ephemeral and do not flow except after 1 or more inches of precipitation.

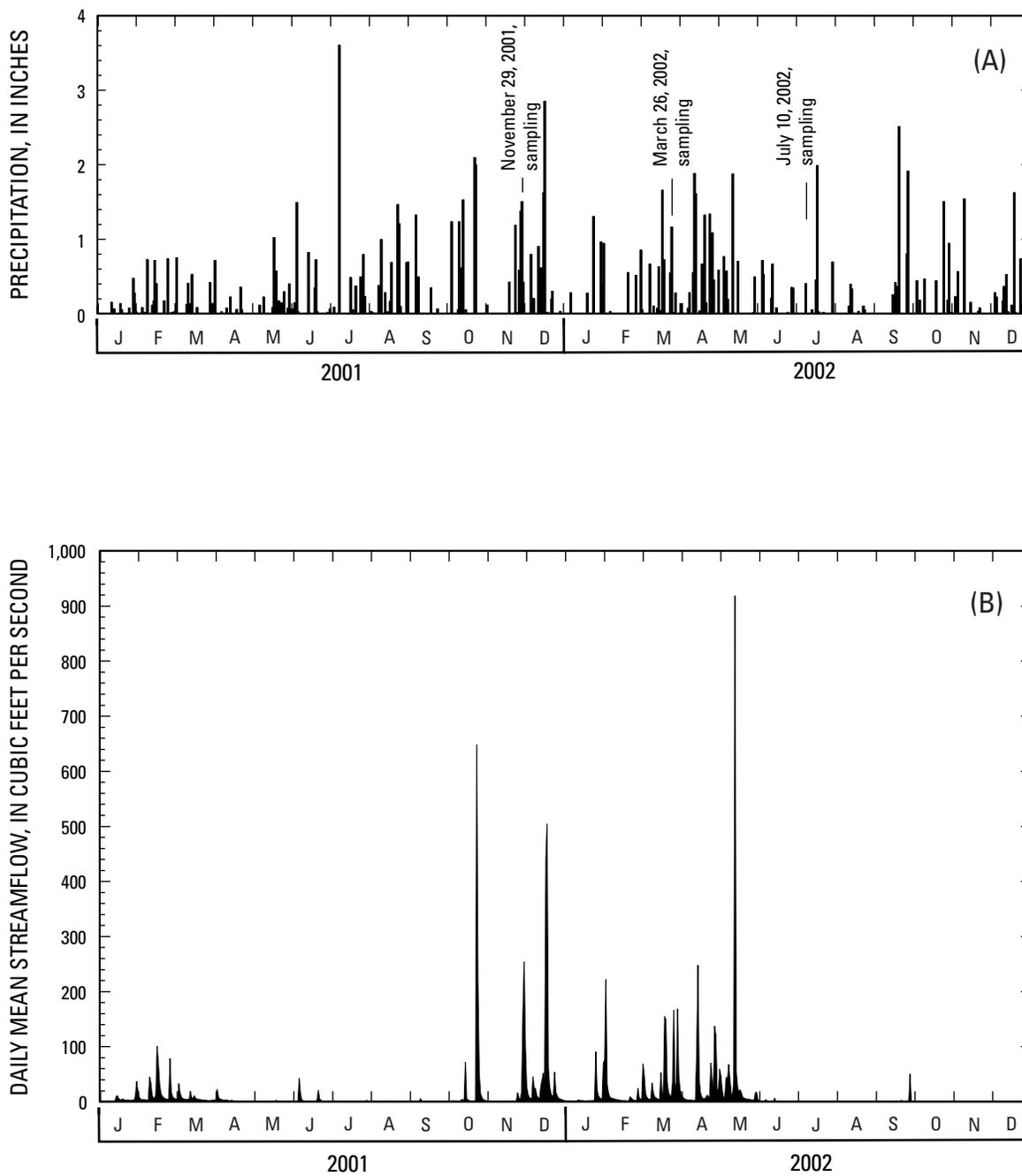
Water-quality sampling and streamflow measurements were attempted on November 29, 2001, March 26, 2002, and July 10, 2002, in response to Doppler-radar estimates of precipitation and observations of runoff by NPS staff. Precipitation records from the NWS-COP Boonville weather station indicated 3.5 in. of precipitation fell between November 27 and November 29, 2001 (fig. 5) (Purdue University, 2004). Doppler-radar images of precipitation totals for the November 2001 sampling indicated that an estimated 3 to 5 in. of precipitation (fig. 6) fell in the park area during a 3-day period before the sampling and discharge measurements were made (National Oceanic and Atmospheric Administration, 2001). Daily mean

streamflows of 19, 165, and 254 ft<sup>3</sup>/s were reported on November 27, 28, and 29, 2001, respectively, for the closest USGS streamflow-gaging station to the park (station number 03303400) on Crooked Creek near Santa Claus, Indiana (Stewart and others, 2003, p. 98). This gaging station is about 6 mi east of the park (fig. 2); however, it is in a different drainage basin outside the park and is referred to as an indication of local streamflow resulting from precipitation (fig. 5). The median of daily mean streamflows at this gaging station between 1970 and 2002 was 1.7 ft<sup>3</sup>/s. Daily mean streamflows during this period were 22 ft<sup>3</sup>/s or less, 90 percent of the time (Stewart and others, 2003, p. 98).

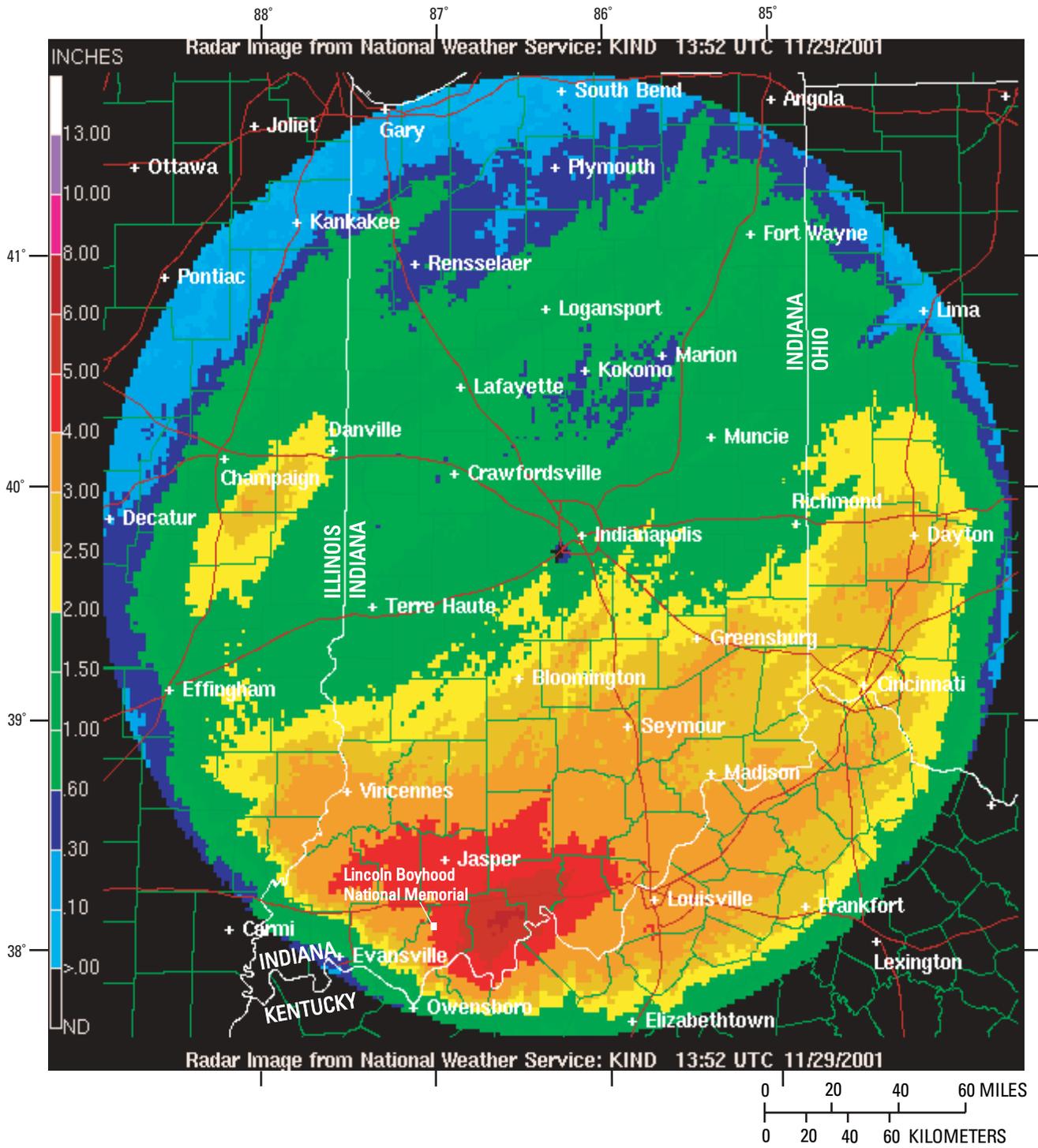
Precipitation records from the NWS-COP Boonville weather station indicated about 1.2 in. of precipitation fell from March 25 to March 26, 2002 (Purdue University, 2004). Doppler-radar images of precipitation totals for the March 2002 sampling indicated that between 1.0 and 2.5 in. of precipitation (fig. 7) were estimated to have fallen in the park area during a 23-hour period ending at about 1:30 p.m. on March 26, 2002 (National Oceanic and Atmospheric Administration, 2002). Daily mean streamflows of 34 and 166 ft<sup>3</sup>/s were reported on March 25 and 26, 2002, respectively, at Crooked Creek near Santa Claus, Indiana (Stewart and others, 2003, p. 98). During the 24 hours preceding the July 10, 2002, sampling, 0.41 in. of precipitation was recorded at the NWS-COP Boonville weather station (Purdue University, 2004) and daily mean streamflow increased only to 0.04 ft<sup>3</sup>/s at the closest USGS streamflow-gaging station to the park (station number 03303400) on July 10, 2002 (Stewart and others, 2003, p. 98).

Streamflows measured at the sampling sites were smaller than those measured at the USGS streamflow-gaging station (station number 03303400) on Crooked Creek near Santa Claus, Indiana; this difference was expected. The drainage areas of the sampling sites in the park can be measured in hundredths to tenths of square miles, whereas the drainage area contributing to the USGS streamflow-gaging station (station number 03303400) on Crooked Creek near Santa Claus, Indiana, was 7.86 mi<sup>2</sup> (Stewart and others, 2003, p. 98). Discharge, surface-water-, and ground-water-quality data for the park sites are listed in table 4. During the November 29, 2001, sampling, stream discharges were 0.21 ft<sup>3</sup>/s in ephemeral stream 3, 0.08 ft<sup>3</sup>/s in parking-lot runoff, and 0.21 ft<sup>3</sup>/s in the unnamed ditch. During the March 26, 2002, sampling, stream discharges were 0.21 ft<sup>3</sup>/s in ephemeral stream 3, 0.01 ft<sup>3</sup>/s in parking-lot runoff, and 0.20 ft<sup>3</sup>/s in the unnamed ditch. Small flows were observed in ephemeral stream 3 and the unnamed ditch by NPS staff on the morning of July 10, 2002; no flow was observed at those sites when they were visited for sampling by USGS personnel later that day. Therefore, on July 10, 2002, samples were collected only from the stock pond and Lincoln Spring. The total depth of the stock pond was about 4.5 ft during each sampling.

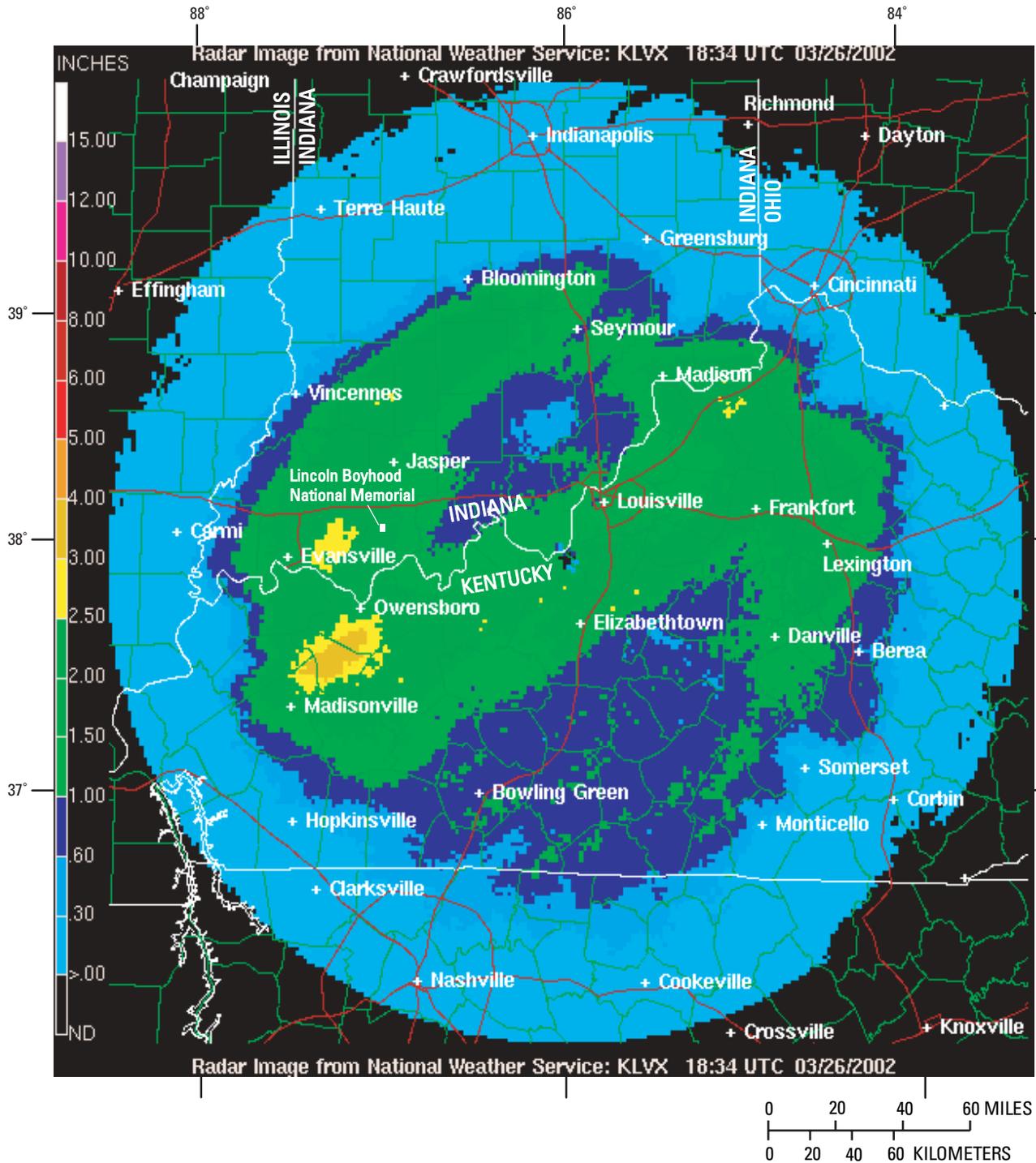
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**Figure 5.** Sampling dates at the Lincoln Boyhood National Memorial near Lincoln City, Indiana, during the study period, plotted with (A) the precipitation record for National Weather Service Cooperative Observer Program weather station, Boonville, Indiana, and (B) a hydrograph for the nearest U.S. Geological Survey streamflow-gaging station (03303400, Crooked Creek near Santa Claus, Indiana), January 2001 to December 2002.



**Figure 6.** Doppler-radar image of total storm precipitation for Indiana, November 26–29, 2001, from National Weather Service, Indianapolis, Indiana.



**Figure 7.** Doppler-radar image of total storm precipitation for Indiana, March 25–26, 2002, from National Weather Service, Louisville, Kentucky.

## Surface-Water and Ground-Water Quality

Nine surface-water samples and one ground-water sample were collected for this study. Because only one ground-water-quality sample was collected during this study, sample results are discussed with the results of surface-water analyses. The values of the water-quality characteristics and chemical constituents are listed in table 4. Data for water-quality characteristics and chemical constituents analyzed in quality-assurance samples are listed in table 5 (back of report). Surface-water-quality data from sites near the park that were collected for other studies in 1979 and 2000 (Renn and others, 1980; Renn, 1983; and Silcox and others, 2002) and that are used to compare with data collected for this study are listed in table 6 (back of report).

### Physical Properties

Dissolved-oxygen concentrations in surface water ranged from 4.8 mg/L on July 10, 2002, to 11.8 mg/L on March 26, 2002; the minimum and maximum concentrations were in water samples from the stock pond (table 4). State of Indiana water-quality standards for surface water require that concentrations of dissolved oxygen average at least 5.0 mg/L per day and not be less than 4.0 mg/L for any single measurement (Indiana Administrative Code, 1997, p. 7). The dissolved-oxygen concentration (<0.1 mg/L) of a ground-water sample from Lincoln Spring was nearly anaerobic in a sample collected on July 10, 2002. There are no Indiana standards for dissolved-oxygen concentrations in ground water.

Dissolved-oxygen concentrations in the March 26, 2002, surface-water samples from the park (table 4) were larger than those reported by other studies for surface-water samples from sites near the park (table 6, back of report). Dissolved-oxygen concentrations in the March 26, 2002, surface-water samples ranged from 10.1 mg/L in parking-lot runoff to 11.8 mg/L in the stock pond. The range of dissolved-oxygen concentrations (from 4.8 mg/L to 9.2 mg/L) in all other surface-water samples from the park was more similar to the range of concentrations reported by previous studies from sites near the park.

Dissolved-oxygen concentrations in surface-water samples in 1979 data reported by Renn and others (1980) from five sites near the park (table 6, back of report) ranged from 3.5 mg/L (site 267 on Little Pigeon Creek) to 9.5 mg/L (site 277 on Buckhorn Creek). Approximate locations of these sites are shown in figure 2 (Renn and others, 1980, figs. 17 and 23); exact latitudes and longitudes were not determined by that study. Dissolved-oxygen concentrations ranged from 1.3 mg/L to 8.8 mg/L in July and August 2000 surface-water samples (Silcox and others, 2002) from site 34 on Crooked Creek (table 6, back of report); all but one value were less than those reported for surface-water samples from the park. Dissolved-oxygen concentrations in July and August 2000 (Silcox and others, 2002) surface-water samples from site 35 on Little Pigeon Creek ranged from 4.2 mg/L to 5.6 mg/L (table 6, back of report).

In surface-water samples from the park (table 4), pH values ranged from 6.2 to 7.9. The November 29, 2001, surface-water sample from ephemeral stream 3 was acidic (6.2); the March 26, 2002, sample of parking-lot runoff was alkaline (7.9). These values were within the pH range of 6.0 to 9.0 allowed under State of Indiana surface-water-quality standards (Indiana Administrative Code, 1997, p. 7). The pH in river water in areas not affected by contamination generally is in the range of 6.5 to 8.5 (Hem, 1989, p. 64). The pH of the ground-water sample from Lincoln Spring was more acidic (5.9) than that of the surface-water samples.

The range of pH values of surface-water samples from the park (table 4) was larger than the range of pH values measured in surface-water samples by other studies from sites near the park (table 6, back of report). Measurements of pH in surface water in 1979 reported for five sites near the park (Renn and others, 1980) ranged from 6.2 to 7.4 (both from site 267 on Little Pigeon Creek; table 6, back of report). Field pH values for July and August 2000 (Silcox and others, 2002) surface-water samples from site 34 on Crooked Creek ranged from 6.9 to 7.6 (table 6, back of report). Field pH values for July and August 2000 (Silcox and others, 2002) surface-water samples from site 35 on Little Pigeon Creek ranged from 6.8 to 7.6 (table 6, back of report).

Suspended-sediment concentrations (table 4) were the largest in samples from the stock pond (30 mg/L in the March 26, 2002, sample) and the unnamed ditch (32 mg/L in the November 29, 2001, sample). The suspended-sediment concentration in the November 29, 2001, sample from the unnamed ditch is an estimated value; the concentration reported for a sequential duplicate sample (23 mg/L) was more than 25 percent different than the surface-water sample (table 5, back of report). Suspended-sediment values were smallest in two samples of parking-lot runoff (7.2 mg/L and 9.4 mg/L). Turbidity values were largest in the stock pond sample (28 NTU and 43 NTU) and smallest in samples from ephemeral stream 3 (13 NTU and 16 NTU). Almost no suspended sediment was determined in the ground-water sample from Lincoln Spring (0.3 mg/L). The turbidity value of ground water from Lincoln Spring also was small (0.7 NTU); the water was visibly clear at the time of sampling.

Specific-conductance values for all surface-water samples collected for this study were less than 175  $\mu\text{S}/\text{cm}$  (table 4). By comparison, specific conductance of ground water from Lincoln Spring was 837  $\mu\text{S}/\text{cm}$ . Specific conductance is proportionate to dissolved-solids concentrations; that is, larger values of specific conductance indicate larger concentrations of dissolved solids (Hem, 1989).

The values of specific conductance for surface-water samples from the park (table 4) were less than those measured by other studies in surface water from sites near the park (table 6, back of report). Measurements of specific conductance in surface water in 1979 data from five sites near the park (Renn and others, 1980) ranged from 270  $\mu\text{S}/\text{cm}$  (site 277 on Buckhorn Creek) to 580  $\mu\text{S}/\text{cm}$  (site 267 on Little Pigeon Creek) (table 6, back of report). Specific-conductance values for July and

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August 2000 (Silcox and others, 2002) surface-water samples from site 34 on Crooked Creek ranged from 357  $\mu\text{S}/\text{cm}$  to 736  $\mu\text{S}/\text{cm}$  (table 6, back of report). Specific-conductance values for July and August 2000 (Silcox and others, 2002) surface-water samples from site 35 on Little Pigeon Creek ranged from 302  $\mu\text{S}/\text{cm}$  to 2,000  $\mu\text{S}/\text{cm}$  (table 6).

### Major Ions and Nutrients

Concentrations of dissolved major ions, nitrite plus nitrate (hereafter referred to as nitrate), nitrite, ammonia, and total phosphorus in the nine surface-water samples and one ground-water sample collected in 2001 and 2002 from key water bodies in the park are listed in table 4. Results of quality-assurance samples for these same constituents in three equipment blank samples and three sequential duplicate samples collected in the same study are listed in table 5 (back of report). Results from the analysis of surface-water samples collected in 1979 from the closest downstream site to the park with data for major ions and nutrients (site 267 on Little Pigeon Creek; Renn and others, 1980) are listed in table 7 (back of report).

### Analysis of Water-Quality Samples

Calcium was the predominant cation in all surface-water samples collected from the park (fig. 8 and table 4). Sulfate was the predominant anion for samples from ephemeral stream 3 and for two of the three samples from the stock pond. Bicarbonate, as estimated from alkalinity concentrations, was the predominant anion in samples from parking-lot runoff and the unnamed ditch and in the July 10, 2002, sample from the stock pond. Bicarbonate concentrations were estimated by dividing alkalinity concentrations (reported as calcium carbonate) by a conversion factor (0.8202) reported by Hem (1989, p. 55). For the pH range of water-quality samples collected by this study (5.9 to 7.9), the alkalinity of most natural waters can be assumed, without serious error, to originate entirely from dissolved bicarbonate ion (Hem, 1989, p. 106). Concentrations of calcium, magnesium, potassium, sodium, chloride, and sulfate in 2001 and 2002 surface-water samples from the park sites were smaller than concentrations reported for the 1979 samples from site 267 on Little Pigeon Creek (table 4; table 7, back of report).

National Atmospheric Deposition Program National Trends Network (NADP/NTN) site IN22, about 50 mi northwest of the park (fig. 1), is the closest wet-deposition monitoring station to the study area. Wet-deposition samples include precipitation and any particulate matter that is collected with the samples. A comparison of data on major ions and nutrients was made between surface-water samples from the park and volume-weighted mean concentrations for those constituents in wet deposition from NADP/NTN (National Atmospheric Deposition Program, 2004) site IN22. Concentrations of the major cations and anions in surface-water samples collected from the park were larger than the annual volume-weighted mean concentrations in weekly wet-deposition samples at site IN22

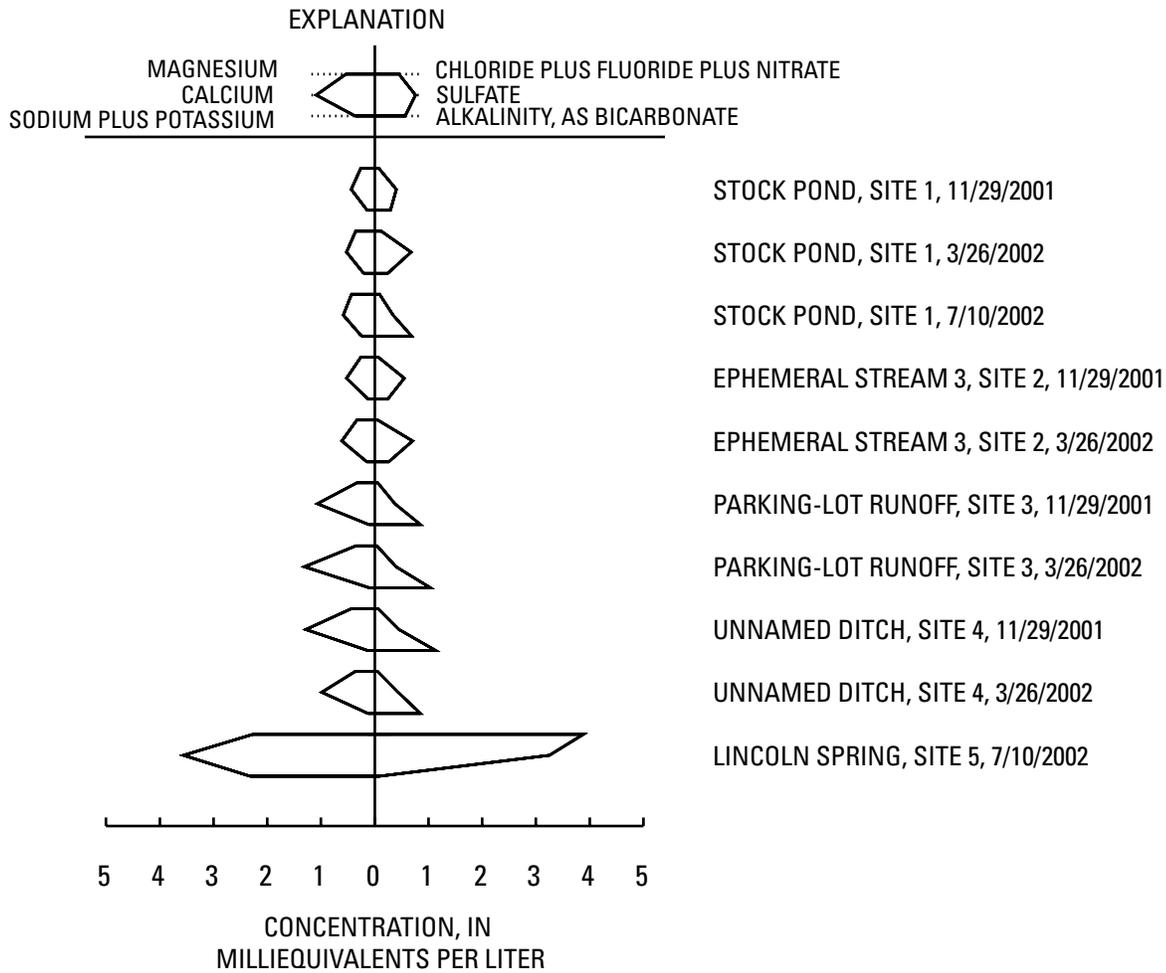
(table 8), except for ammonium and nitrate. The data comparison indicates that sources such as mineral dissolution or human-influenced contamination may contribute more major cations and anions to surface water sampled in this study than wet deposition did. The nitrate concentrations in surface water were similar to or less than the volume-weighted mean nitrate concentrations in weekly wet-deposition samples from site IN22 (fig. 1 and table 8) (National Atmospheric Deposition Program, 2004). These data indicate it is possible that wet-deposition-derived nitrate may be a major contributor to the nitrate concentrations in surface-water samples from the park.

Surface-water-quality data from the park represent baseline conditions for the area in relation to data available from previous studies of area streams. In general, concentrations of most major ions and various nutrients in surface-water samples from the park were smaller than those reported for samples collected in other USGS studies in areas adjacent to the park. Much of the data are from a 1979 study; the age of that data may be a factor in comparisons with data in this study.

Concentrations of all major cations and anions, except fluoride, were largest in the ground-water sample from Lincoln Spring relative to the other samples collected for this study (table 4). Calcium and chloride were the principal cation and anion, respectively, in water from Lincoln Spring (fig. 8). The equivalent concentration of sulfate was about 0.25 milliequivalent per liter less than that of chloride. The equivalent concentrations of sodium and magnesium in water from Lincoln Spring were nearly equal and were larger than their concentrations in the other samples collected for this study. Water from Lincoln Spring had a larger dissolved-solids concentration when compared with the surface-water samples from the park (table 4).

The concentration of nitrate in water from Lincoln Spring was 16.5 mg/L as nitrogen (N). This concentration was larger than the State of Indiana water-quality criteria, as derived from the Indiana drinking-water standard (10 mg/L as N) (table 9). Regular consumption of drinking water with nitrate concentrations that exceed 10 mg/L as N has been associated with methemoglobinemia in small children (Hem, 1989) and possibly may be associated with larger numbers of miscarriages (Centers for Disease Control, 1996).

The nitrate concentration in water from Lincoln Spring is in the range that indicates a human influence on ground-water quality (Madison and Brunett 1984, p. 95). Potential sources of the nitrate concentration in ground water from Lincoln Spring include local domestic wastewater disposal, possible effects from local agricultural activities such as the application of fertilizers or chemicals, or unreported spills of nitrogenous materials. The recharge area of Lincoln Spring is not known. Because only one well was sampled, no evaluation could be made of the direction of ground-water flow relative to the park or Lincoln Spring.



STIFF DIAGRAM—Cation and anion concentrations are plotted as points and connected by lines into a closed pattern. The pattern indicates predominant cations and anions in a water-quality analysis. The width of the pattern approximately indicates the dissolved-solids content of the water. Cations include magnesium (Mg), calcium (Ca), sodium (Na), and potassium (K). Anions include chloride (Cl), fluoride (F), nitrate (NO<sub>3</sub>), sulfate (SO<sub>4</sub>), and bicarbonate (HCO<sub>3</sub>).

A milliequivalent is defined as a weight of a chemical substance divided by the formula weight of its composition elements and the assumed charge of the species. For example, calcium and magnesium have assumed charges of 2, and sodium and potassium have assumed charges of 1.

**Figure 8.** Stiff diagrams showing the relation of major ions in surface-water and ground-water samples from sampling sites at the Lincoln Boyhood National Memorial near Lincoln City, Indiana, 2001 and 2002.

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**Table 8.** Summary of volume-weighted mean concentrations for samples of wet deposition from site IN22, National Atmospheric Deposition Program National Trends Network, and range of concentrations in surface-water samples at the Lincoln Boyhood National Memorial near Lincoln City, Indiana, 2001–02.

[Park, Lincoln Boyhood National Memorial; all concentrations in milligram per liter, < , less than]

Constituent name	Volume-weighted mean concentrations of weekly samples		Concentration range for park surface-water samples, 2001–02
	2001 data	2002 data	
Calcium	0.17	0.18	8.74 - 26.2
Magnesium	.024	.024	3.11 - 5.27
Potassium	.051	.036	.96 - 3.23
Sodium	.060	.087	1.12 - 3.76
Chloride	.13	.15	1.17 - 4.09
Sulfate	1.68	1.75	16.5 - 33.9
Ammonium, as nitrogen	.26	.32	<.01 - .04
Nitrate, as nitrogen	1.11	1.08	<.05 - 1.25 <sup>1</sup>
Number of valid samples used for statistic	41	41	9 (5 samples for ammonia)

<sup>1</sup>Concentration range of nitrate as nitrogen for water samples from the park computed as the difference between nitrate plus nitrate concentrations and nitrite concentrations.

The redox chemistry of the ground-water sample from Lincoln Spring is more anaerobic than that of the surface-water samples collected for this study. The lack of dissolved oxygen, the abundant nitrate, the lack of nitrite, and the trace detection of ammonia in the Lincoln Spring sample indicate a redox condition that has the potential to support denitrification. More information is needed, however, to evaluate whether denitrification actually is occurring in ground water at Lincoln Spring.

Water from the stock pond contained trace concentrations of ammonia (0.01 and 0.04 mg/L as N), nitrate (0.02 mg/L as N, estimated concentration, to 0.25 mg/L as N), nitrite (0.004 mg/L as N, estimated concentration; 0.005 mg/L as N, estimated concentration; and <0.008 mg/L as N), and phosphorus (0.07 to 0.08 mg/L as phosphorus or P) (table 4). Nitrite concentrations were smaller than the concentrations of nitrate in these samples. A small number of livestock use the pasture and stock pond; the small concentrations of nutrients in the stock pond water sample may reflect animal-related loading of nutrients as well as wet deposition and soil-derived nutrients.

Differences in water-quality data between sites indicate that parking-lot runoff is a source of calcium, alkalinity, and phosphorus in the unnamed ditch. Concentrations of calcium, alkalinity, and phosphorus were larger in the samples collected from the unnamed ditch and in parking-lot runoff than in those collected from ephemeral stream 3. The unnamed ditch receives flow from ephemeral stream 3, parking-lot runoff, and upstream as it parallels the Hoosier Southern Railroad track. Calcium concentrations increased between samples from ephemeral stream 3 (10.5 mg/L and 12.3 mg/L) and the unnamed ditch (25.7 mg/L and 19.8 mg/L) (table 4). Calcium concentrations in parking-lot-runoff samples (21.4 mg/L and 26.2 mg/L) were similar to those in water samples from the unnamed ditch. Similar concentration patterns were observed for calcium carbonate and phosphorus. Sulfate concentrations were smaller in samples collected from the unnamed ditch and in parking-lot runoff than in those collected from ephemeral stream 3. The data indicate that sulfate concentrations from ephemeral stream 3 likely are diluted by parking-lot runoff.

**Table 9.** State of Indiana water-quality criteria for specific substances, Indiana Administrative Code (327 Article 2).

[C, Indiana water-quality standard derived from nonthreshold cancer risk; D, Indiana water-quality standard derived from drinking-water standards, equal to or less than threshold toxicity; T, Indiana water-quality standard derived from threshold toxicity; --, no criteria]

Substances	Aquatic life (Acute aquatic criteria <sup>1</sup> )	Continuous criterion concentration (4-day average)			
		Outside mixing zone		Point of water intake	
		Aquatic life (Chronic aquatic criteria)	Human health	Human health	Human health
<b>Trace metals (concentrations in microgram per liter)</b>					
Arsenic (total or valence III)	360	190	0.175	(C)	0.022
Barium	--	--	--	(D)	1,000
Cadmium	$e^{(1.128 [\ln \text{Hardness}] - 3.828)}$	$e^{(0.7852 [1n \text{Hardness}] - 3.490)}$	10	--	--
Chromium (total or valence III)	$e^{(0.8190 [\ln \text{Hardness}] + 3.688)}$	$e^{(0.8190 [1n \text{Hardness}] + 1.561)}$	3,433,000	(T)	170,000
Copper	$e^{(0.9422 [\ln \text{Hardness}] - 1.464)}$	$e^{(0.8545 [1n \text{Hardness}] - 1.465)}$	--	--	--
Lead	$e^{(1.273 [\ln \text{Hardness}] - 1.460)}$	$e^{(1.273 [1n \text{Hardness}] - 4.705)}$	--	(D)	50
Nickel	$e^{(0.8460[\ln \text{Hardness}] + 3.3612)}$	$e^{(0.8460 [1n \text{Hardness}] + 1.1645)}$	100	--	13.4
Selenium	130	35	--	(D)	10
Silver	$0.5 \times e^{(1.72[\ln \text{Hardness}] - 6.52)}$	--	--	(D)	50
Zinc	$e^{(0.8473[\ln \text{Hardness}] + 0.8604)}$	$e^{(0.8473 [1n \text{Hardness}] + 0.7614)}$	--	--	--
<b>Other substances (concentrations in milligram per liter)</b>					
Chloride	860	230	--	--	--
Fluoride	2.0	--	--	--	--
Dissolved solids or total residue	750	--	--	--	--
Sulfate	250	--	--	--	--
Nitrite plus nitrate, as nitrogen	--	--	--	(D)	10
Nitrite, as nitrogen	--	--	--	(D)	1.0

<sup>1</sup>The Indiana chronic aquatic criterion (CAC) for lead is calculated with the calcium-carbonate hardness concentration in the sample and the following equation from the Indiana Water Pollution Control Board subsection 327 IAC 2-1-6(a)(3)2 (Indiana Administrative Code, 1997). Other CAC and acute aquatic criteria (AAC) reference this convention in how their values are derived.

$$\text{Chronic aquatic criteria (lead)} = e^{1.273 [\ln \text{Hardness}] - 4.705}$$

where

- e is the base of the natural logarithm,
- ln is the natural logarithm, and
- hardness is the calcium-carbonate hardness concentration in milligrams per liter as calcium carbonate (CaCO<sub>3</sub>).

### Quality-Assurance Analysis Results

Statistics computed from paired water-quality and sequential duplicate samples from the same source indicated that chemical analyses of all major ions and nutrients met the precision standard for this study (table 10). The maximum RPD in concentrations for paired water-quality and sequential duplicate sample analyses of major cations and nutrients ranged from 0.53 for sulfate analyses to 23.3 for fluoride analyses. When only those major ions and nutrients with mean concentrations greater than 1 mg/L are considered, the largest maximum RPD in concentrations for paired water-quality and sequential duplicate sample analyses was 10.1 for alkalinity.

The differences between the equivalent concentrations of major cations (calcium, magnesium, sodium, and potassium) and major anions (chloride, sulfate, bicarbonate estimated from alkalinity, nitrate, and fluoride) were 6 percent or less for all samples from park sites (table 11). These differences were computed, using the procedure outlined by Hem (1989, p. 164). The largest differences were in the samples of parking-lot runoff. Hem (1989, p. 164) indicates that differences larger than 3 percent are acceptable for waters with less than 5 milliequivalents per liter of all major cations and anions. Based on this standard, there are no apparent errors in concentrations of major anions and cations in the surface-water samples collected for this study; however, there may be small errors in those concentrations in the sample from Lincoln Spring.

Results of quality-assurance analyses indicated that the nitrate concentration from Lincoln Spring met analytical-precision criteria for paired water-quality and sequential duplicate analyses. The nitrate concentration was 16.5 mg/L as N for the ground-water sample at Lincoln Spring (table 4). The nitrate concentration was 17.4 mg/L as N for the sequential duplicate sample from Lincoln Spring (table 5); this concentration is an indication that the analytical results were reproducible. In addition, the estimated nitrate concentration was 0.04 mg/L as N (table 5) for the equipment blank collected earlier the same day as the sequential duplicate; this result is an indication that there was little or no nitrate contributed to the sample through the sampling process. Similar quality-assurance results also were reported for other major-ion and nutrient analyses.

The differences in calcium and sulfate concentrations between samples from surface-water sites that are attributed to parking-lot runoff are larger than the differences between analyses of paired water-quality and sequential duplicate samples (tables 4 and 10). It could not be determined whether the larger phosphorus concentrations in samples of parking-lot runoff and from the unnamed ditch, as compared to those from ephemeral stream 3, were a result of analytical variability. The magnitude of increased concentrations of phosphorus in these samples were within the range of differences in concentrations observed between paired water-quality and sequential duplicate samples.

### Trace Metals and Organic Constituents

Concentrations of trace metals and organic constituents in the nine surface-water samples and one ground-water sample collected at the park are listed in table 4. Results of quality-assurance samples for these same constituents in three equipment blank samples and three sequential duplicate samples are listed in table 5 (back of report). Results from the analyses of surface-water samples collected in 1979 from the closest downstream site to the park with data for trace metals (site 267 on Little Pigeon Creek; Renn and others, 1980) are listed in table 6 (back of report).

#### Analysis of Water-Quality Samples

Concentrations of seven trace metals (arsenic, cadmium, chromium, copper, lead, selenium, and zinc) and dissolved concentrations of iron and manganese were detected in the water-quality samples collected at the park by this study. Nickel and silver were not detected in any of the water samples (table 4). Concentrations of lead in water samples from the stock pond, parking-lot runoff, and the unnamed ditch collected in November 2001 and March 2002 exceeded the chronic aquatic criteria set by the State of Indiana (table 12). The purpose of setting chronic aquatic criteria is to ensure that the concentration of a defined substance does not produce chronic effects on aquatic organisms (Indiana Administrative Code, 1997, p. 15). Concentrations of all other trace metals analyzed for this study were smaller than their chronic aquatic criteria. Cadmium concentrations in water samples from the stock pond on the same dates ranged from 66 to 80 percent of the magnitude of the chronic aquatic criteria for cadmium (table 12). The chronic aquatic criteria for trace metals were computed, using the hardness values listed in tables 4 and 12. Hardness values for these data were computed, using the equation defined in Hem (1989, p. 158):

$$\text{Hardness (mg/L as CaCO}_3\text{)} = (\text{Calcium [in mg/L]} \times 0.0499 + \text{Magnesium [in mg/L]} \times 0.08229) \times 50 \quad (2)$$

where

mg/L is milligram per liter, and  
CaCO<sub>3</sub> is calcium carbonate.

Concentrations of iron ranged from 99  $\mu\text{g/L}$  to 226  $\mu\text{g/L}$  (table 4) in surface-water samples from the park and were greater than the iron concentration in ground water from Lincoln Spring (25  $\mu\text{g/L}$ ). Manganese concentrations in two of three samples from the stock pond (251  $\mu\text{g/L}$  and 371  $\mu\text{g/L}$ ) were more similar in magnitude to the manganese concentration (322  $\mu\text{g/L}$ ) of the Lincoln Spring ground-water sample than any of the other surface-water samples. Manganese concentrations in all other surface-water samples ranged from 3.8  $\mu\text{g/L}$  to 64.7  $\mu\text{g/L}$ .

**Table 10.** Statistical analysis of paired water-quality and sequential duplicate samples from the Lincoln Boyhood National Memorial, near Lincoln City, Indiana, 2001–02, that was used to assess the reproducibility of analytical methods.

[mg/L, milligram per liter; CaCO<sub>3</sub>, calcium carbonate; SiO<sub>2</sub>, silica; N, nitrogen; P, phosphorus; µg/L, microgram per liter; --, not available or known]

Water-quality characteristics (units)	Number of paired water-quality and sequential duplicate samples <sup>1,2</sup>	Mean concentration of paired water-quality and sequential duplicate samples <sup>2,3</sup>		Absolute difference between paired water-quality and sequential duplicate samples <sup>4</sup>		Absolute relative percent difference between paired water-quality and sequential duplicate samples <sup>5</sup>	
		Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
Calcium, dissolved (mg/L)	3	20.0	70.1	0.05	2.29	0.20	3.26
Magnesium, dissolved (mg/L)	3	4.38	27.3	.02	.67	.31	2.46
Potassium, dissolved (mg/L)	3	1.40	8.42	.02	.67	.77	7.96
Sodium, dissolved (mg/L)	3	1.63	47.7	.01	1.13	.77	2.37
Alkalinity (mg/L as CaCO <sub>3</sub> )	3	5.52	68.8	.11	.56	.16	10.1
Chloride, dissolved (mg/L)	3	1.59	128	.00	.47	.00	1.99
Fluoride, dissolved (mg/L)	3	.09	.12	.00	.03	3.42	23.3
Silica, dissolved (mg/L as SiO <sub>2</sub> )	3	11.1	24.6	.04	.32	.37	1.32
Sulfate, dissolved (mg/L)	3	20.9	156	.04	.74	.19	.53
Nitrite plus nitrate, dissolved (mg/L as N)	3	.05	17.0	.00	.82	.00	6.19
Phosphorus, total (mg/L as P)	2	.05	.06	.00	.01	6.25	20.4
Arsenic, total (µg/L)	1	--	1.42	--	.25	--	17.7
Chromium, total (µg/L)	1	--	.46	--	.01	--	2.78
Copper, total (µg/L)	3	1.35	10.9	.05	.51	2.01	22.2
Iron, dissolved (µg/L)	3	26.4	192	.59	8.34	.46	11.3

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**Table 10.** Statistical analysis of paired water-quality and sequential duplicate samples from the Lincoln Boyhood National Memorial, near Lincoln City, Indiana, 2001–02, that was used to assess the reproducibility of analytical methods.—Continued

[mg/L, milligram per liter; CaCO<sub>3</sub>, calcium carbonate; SiO<sub>2</sub>, silica; N, nitrogen; P, phosphorus; µg/L, microgram per liter; --, not available or known]

Water-quality characteristics (units)	Number of paired water-quality and sequential duplicate samples <sup>1,2</sup>	Mean concentration of paired water-quality and sequential duplicate samples <sup>2,3</sup>		Absolute difference between paired water-quality and sequential duplicate samples <sup>4</sup>		Absolute relative percent difference between paired water-quality and sequential duplicate samples <sup>5</sup>	
		Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
Lead, total (µg/L)	3	1.15	6.16	0.00	1.05	0.00	17.0
Manganese, dissolved (µg/L)	3	8.14	319	.00	6.14	.00	1.92
Selenium, total (µg/L)	1	--	1.10	--	.06	--	5.58
Organic carbon, total (mg/L)	2	5.18	10.0	.08	.62	1.54	6.22
Suspended sediment (mg/L)	2	19.0	27.5	0	9	0	32.7

<sup>1</sup>Sequential duplicate samples are two samples that are collected, one immediately after the other. Both samples were shipped, processed, and analyzed in the same manner.

<sup>2</sup>Paired samples with one or both samples having concentrations less than the reporting limit were not used for this analysis, except for cases where estimated concentrations were reported. Sample concentrations that were reported as estimated (with a magnitude less than the method or lower reporting limit) were set equal to the estimated concentration for computation of statistics.

<sup>3</sup>Sample concentrations used to compute these statistics were unrounded values from the U.S. Geological Survey National Water-Quality Information System database. Statistics reported in this table were rounded to two decimal places.

<sup>4</sup>Absolute differences were computed as the absolute value of the concentration in the sequential duplicate sample minus the concentration in the paired water-quality sample.

<sup>5</sup>Absolute relative percent differences (RPD) were computed as

$$RPD = |(SDS - WQS) / ((SDS + WQS) / 2)| \times 100$$

where

*RPD* is the relative percent difference,

*SDS* is the concentration in the sequential duplicate sample, and

*WQS* is the concentration in the water-quality sample.

This statistic is used to summarize the relative percent difference in concentrations between two samples that should be identical in composition and that were identical in their handling and analysis.

**Table 11.** Differences in cation and anion equivalent concentrations in water samples collected at the Lincoln Boyhood National Memorial, near Lincoln City, Indiana, 2001–02.

[mm/dd/yyyy, month/day/year]

Site name	Date sampled (mm/dd/yyyy)	Percent difference between equivalent concentrations of cations and anions	Total concentration of all major cations and anions, in milliequivalents per liter
Stock pond (site 1)	11/29/2001	0.2	1.7
Stock pond (site 1)	03/26/2002	.8	2.2
Stock pond (site 1)	07/10/2002	.4	2.5
Ephemeral stream 3 (site 2)	11/29/2001	.3	1.8
Ephemeral stream 3 (site 2)	03/26/2002	.7	2.2
Parking-lot runoff (site 3)	11/29/2001	1.1	3.0
Parking-lot runoff (site 3)	03/26/2002	2.0	3.5
Unnamed ditch (site 4)	11/29/2001	1.3	3.7
Unnamed ditch (site 4)	03/26/2002	1.7	3.0
Lincoln Spring (site 5)	07/10/2002	6.0	15.4

**Table 12.** Summary of surface-water- and ground-water-quality samples with nitrate, cadmium, or lead concentrations that are within or larger than 60 percent of the Indiana water-quality criteria (Indiana Administrative Code, 327), the Lincoln Boyhood National Memorial, near Lincoln City, Indiana, 2001–02.

[mm/dd/yyyy, month/day/year; mg/L, milligram per liter; N, nitrogen; POWI–HH, point of water intake–health hazard; CAC, chronic aquatic criteria;  $\mu\text{g/L}$ , microgram per liter;  $\text{CaCO}_3$ , calcium carbonate]

Constituent name	Site name	Date sampled (mm/dd/yyyy)	Constituent concentration	Name of surface-water-quality criteria	Surface-water-quality criteria concentration	Remarks
Nitrate	Lincoln Spring (site 5)	07/10/2002	16.5 mg/L as N	POWI–HH	10.0 mg/L	None
Cadmium, total	Stock pond (site 1)	11/29/2001	.4 $\mu\text{g/L}$	CAC	.5 $\mu\text{g/L}$	Computed hardness: 35 mg/L as $\text{CaCO}_3$
		03/26/2002	.4 $\mu\text{g/L}$	CAC	.6 $\mu\text{g/L}$	Computed hardness: 44 mg/L as $\text{CaCO}_3$
Lead, total	Stock pond (site 1)	11/29/2001	1.0 $\mu\text{g/L}$	CAC	.8 $\mu\text{g/L}$	Computed hardness: 35 mg/L as $\text{CaCO}_3$
		03/26/2002	2.0 $\mu\text{g/L}$	CAC	1.1 $\mu\text{g/L}$	Computed hardness: 44 mg/L as $\text{CaCO}_3$
	Parking-lot runoff (site 3)	11/29/2001	5.0 $\mu\text{g/L}$	CAC	2.0 $\mu\text{g/L}$	Computed hardness: 70 mg/L as $\text{CaCO}_3$
		03/26/2002	3.0 $\mu\text{g/L}$	CAC	2.5 $\mu\text{g/L}$	Computed hardness: 83 mg/L as $\text{CaCO}_3$
	Unnamed ditch (site 4)	11/29/2001	7.0 $\mu\text{g/L}$	CAC	3.0 $\mu\text{g/L}$	Computed hardness: 86 mg/L as $\text{CaCO}_3$
		03/26/2002	6.0 $\mu\text{g/L}$	CAC	2.0 $\mu\text{g/L}$	Computed hardness: 67 mg/L as $\text{CaCO}_3$

Concentrations of copper, iron, lead, and organic carbon were larger in the samples collected from the unnamed ditch and parking-lot runoff than in those collected from ephemeral stream 3 during each round of sampling. Concentrations of lead increased between samples from ephemeral stream 3 (detected in concentrations too small to be quantified) and the unnamed ditch (7  $\mu\text{g/L}$  and 6  $\mu\text{g/L}$ ) (table 4). Lead concentrations in samples of parking-lot runoff (5  $\mu\text{g/L}$  and 3  $\mu\text{g/L}$ ) were similar to those in water from the unnamed ditch (7  $\mu\text{g/L}$  and 6  $\mu\text{g/L}$ ). Similar concentration patterns in these samples were observed for iron and organic carbon. These data indicate that parking-lot runoff is likely the primary source of iron, lead, and organic carbon in water from the unnamed ditch.

Parking-lot runoff may be the source of organic carbon in the samples from the unnamed ditch. The presence of organic carbon may indicate the presence of other organic compounds such as polynuclear aromatic hydrocarbons that have been detected in surface water affected by parking-lot runoff. Recent studies in Austin, Texas, of simulated rainfall runoff from coal-tar sealed, asphalt parking lots have found concentrations of polynuclear aromatic hydrocarbons in water and particulate runoff that exceeded the probable-effect concentration for benthic biota (Mahler and others, 2004). The probable-effect concentration, the concentration above which adverse effects on benthic biota are expected to occur more often than not (MacDonald and others, 2000), is 22,800  $\mu\text{g/kg}$  for the sum of polynuclear aromatic hydrocarbons in particulate matter.

Petroleum hydrocarbons (table 4) were detected in two samples collected for this study: in water from the stock pond on November 29, 2001, (2 mg/L) and in ground water from Lincoln Spring on July 10, 2002 (3 mg/L). The detection of petroleum hydrocarbons in ground water from Lincoln Spring could be residual contamination from the nearby spill and cleanup of diesel fuel described earlier in the Site Selection section.

### Quality-Assurance Analysis Results

Results of the quality-assurance analyses indicated that the lead and cadmium concentrations reported here were reproducible and did not represent sampling-related artifacts. The sequential duplicate samples from the unnamed ditch on November 29, 2001, and on March 26, 2002, were nearly identical in lead concentrations to those in the paired water-quality samples (table 4; table 5, back of report). In addition, cadmium concentrations in sequential duplicate samples and in the reported data were less than the reporting limit (less than 0.1  $\mu\text{g/L}$ ). These results indicate that the analytical results for lead and cadmium met precision criteria for the study. In addition, no detectable lead or cadmium was in the equipment blanks collected on the same days as these samples; this result is an indication that there was no lead or cadmium contributed to the samples through the sampling process. Similar quality-assurance results also were reported for other trace-metal analyses.

The changes in iron and lead concentrations attributed to parking-lot runoff are larger than the differences between analyses of paired water-quality and sequential duplicate samples (table 6, back of report). It could not be determined whether the larger copper concentrations in samples of parking-lot runoff and the unnamed ditch, as compared to those from ephemeral stream 3, resulted from a lack of analytical precision. The magnitude of increased concentrations of copper in these samples was within the range of differences in concentrations observed between paired water-quality and sequential duplicate samples (table 4; table 5, back of report). Copper also was detected in an equipment blank (1.7  $\mu\text{g/L}$  on November 29, 2001; table 5) in a concentration similar to those of water-quality samples collected on the same day (1.8 to 2.4  $\mu\text{g/L}$  on November 29, 2001; table 4). It could not be determined whether the larger phosphorus and copper concentrations in samples of parking-lot runoff and the unnamed ditch, as compared to those from ephemeral stream 3, were a result of a lack of analytical precision or a sampling-related interference. Only the copper concentration in water from Lincoln Spring was sufficiently large (11.2  $\mu\text{g/L}$  on July 10, 2002; table 4) to be regarded as free of sample-collection interference.

The reported detections of petroleum hydrocarbons in water from Lincoln Spring are considered to be reliable, based on the interpretation of quality-assurance data. The sequential duplicate sample from Lincoln Spring contained petroleum hydrocarbons (2 mg/L; table 5) in a concentration that was similar to but slightly less than that in the paired water-quality sample (3 mg/L; table 4). The detection of 2 mg/L of petroleum hydrocarbons in an equipment blank sample collected at the stock pond on July 10, 2002 (table 5), was similar in magnitude to the concentrations reported for the water-quality sample from Lincoln Spring collected on the same date (table 4). The water sample collected from the stock pond immediately after the equipment blank preparation, however, did not contain detectable petroleum hydrocarbons. These data indicate the likelihood that the purging of sampled water through the equipment at the time of sampling (as practiced at all sites) was sufficient to purge residual petroleum hydrocarbons from the equipment before surface-water samples were collected.

### *Escherichia coli* Data

The presence of *E. coli* in water often is considered to be direct evidence of the presence of fecal contamination from warm-blooded animals and indicates the possible presence of pathogens (Dufour, 1977). *E. coli* is one of the two preferred indicator bacteria used by the U.S. Environmental Protection Agency (USEPA) and IDEM to determine the suitability of surface water for recreational use. The Indiana water-quality standards for full-body-contact recreational use require the *E. coli* concentration to be less than the single-sample standard of 235 col/100 mL and less than the geometric mean of 125 col/100 mL computed from five samples collected within a 30-day period (Indiana Administrative Code, 1997, p. 10).

The USEPA has set a Maximum Contaminant Level guideline of zero detections of *E. coli* in water sources used for public-water supplies (U.S. Environmental Protection Agency, 2004). Weather conditions and other factors limited sample collection for *E. coli* in water to 1 day of sampling (July 10, 2002).

*E. coli* were detected in water from the stock pond (11 colonies/100 mL) and in water from Lincoln Spring (3 colonies/100 mL) (table 4). Both colony counts were classified as estimates because no sample volume used to prepare the bacteria plates produced a bacteria colony count in the ideal range of 20 to 80 colonies per filter plate. The colony count for the stock pond water sample was less than the recreational-use standard of 235 col/100 mL a single sample. The stock pond is not used as a recreational water body; park workers occasionally may contact the water as part of maintenance activities. The detection of *E. coli* in water from Lincoln Spring exceeded the USEPA's Maximum Contaminant Level guideline. The Lincoln Spring well historically was used as a drinking-water source for local residents before about 1966 but has not been accessed for any purpose since 1996. *E. Coli* counts in the two samples from the park (3 and 11 colonies/100 mL) were less than the range of counts (90 to 13,000 colonies/100 mL) reported by Silcox and others (2002, p. 11) for sites on Little Pigeon Creek and Crooked Creek (table 6, back of report).

No sampling-related interferences were revealed by the quality-assurance sample results. No colonies of *E. coli* were found in the filter blanks, field blank, or the process blank prepared with these samples (table 5, back of report). The sequential duplicate sample from Lincoln Spring was identical to the paired water-quality sample (3 colonies/100 mL) (table 4; table 5, back of report). The latter data indicate that the precision of reported counts of *E. coli*, although based on nonideal counts, met project objectives for data precision.

### Limitations of Data and Interpretations

The timing, frequency, and duration of flow measurements and water-quality-sample collection are critical in monitoring accurate flows and constituent concentrations in small streams because of the rapid response to stormwater runoff and the potentially wide ranges of flow over short periods of time (Church and others, 1999, p. 15). The data collected for this study represent three attempts to collect water samples from areas with ephemeral flows (ephemeral stream 3, parking-lot runoff, and the unnamed ditch) and two perennial water bodies (the stock pond and Lincoln Spring). Water samples from ephemeral sources represented conditions that were sampled 12 hours after the first runoff was generated by precipitation. Limitations of time and travel distance from the USGS Indiana Water Science Center in Indianapolis to the park precluded the collection of the first runoff during a storm. These water samples may not represent the largest values and concentrations of water-quality characteristics in runoff and may not fully indicate water-quality conditions that could represent water-quality issues at the park.

Collection of additional water-quality samples by an unattended, automated sampler could address the need for streamflow data when water-quality changes associated with early stage rainfall runoff are evaluated. Automated stage measurements and establishment of a stage-discharge relation for sampled sites also would be needed to establish the hydrologic context of the water samples. Stormwater flows respond differently to different types of storms and may respond differently to the same type of storm in different seasons. Church and others (1999, p. 15) indicate the critical need for

measurements of flow (that) start at the beginning of the storm, continue through the duration of the event, and are measured at a frequency corresponding to the rate of change of flow and constituent concentrations to ensure the accuracy and representativeness of the resultant flow and pollutant loads.

Because of these conditions, Church and others (1999, p. 15) also recommend that "collection of water-quality data should be synchronized with the timing of flow measurements so that concentrations can be directly applied to measured flows."

## Summary and Conclusions

Water samples were collected from four surface-water sites during storms on November 29, 2001, and March 26, 2002, and from one surface-water site and a well after a rainfall on July 10, 2002, to describe the water quality at key water bodies in the Lincoln Boyhood National Memorial near Lincoln City in southwestern Indiana. This work was done by the U.S. Geological Survey in cooperation with the National Park Service. Key water bodies within the park were defined as follows: (1) a stock pond, to represent possible nonpoint agricultural effects on water quality; (2) an ephemeral stream to represent water quality of drainage from forested and memorial areas of the park; (3) parking-lot runoff to represent water quality related to road and parking lots; (4) an unnamed ditch below the parking lot to represent the effects of the parking-lot runoff and of drainage from an adjacent railroad track on water quality; and (5) Lincoln Spring, a historical ground-water source within the park, to represent localized ground-water conditions near a former diesel-fuel spill. Water samples at the surface-water sites were collected at least twice during rainfall runoff on November 29, 2001, and March 26, 2002; water samples were collected from the stock pond and Lincoln Spring on July 10, 2002. Water samples were analyzed for water-quality characteristics and for concentrations of selected major ions and trace metals, nutrients, organic constituents, and *E. coli* bacteria. Samples for *E. coli* analysis were collected from the stock pond and Lincoln Spring on July 10, 2002.

The pH values for all surface-water samples collected for this study ranged from 6.2 to 7.9; specific-conductance values were less than 175  $\mu\text{S}/\text{cm}$ . The pH level from a ground-water sample from Lincoln Spring was more acidic pH (5.9) than the surface-water samples. The specific conductance of the ground water from Lincoln Spring (837  $\mu\text{S}/\text{cm}$ ) was larger than that of the surface water from the park. The specific conductance of surface water from the park was less than that measured by previous sampling in 1979 and 2000 of surface-water quality at sites near the park. Calcium was the predominant cation in surface-water samples collected from the park and in the ground-water sample from Lincoln Spring. Sulfate was the predominant anion for samples from ephemeral stream 3 and from two of the three samples from the stock pond. Bicarbonate was the predominant anion in samples of parking-lot runoff and the unnamed ditch and in the July 10, 2002, sample from the stock pond. Chloride was the principal anion in the water sample from Lincoln Spring. Concentrations of all major cations and anions and of nitrate were largest in the ground-water sample from Lincoln Spring in comparison to the surface-water samples collected for this study.

Water-quality management issues identified by this sampling include impaired water quality in Lincoln Spring possibly from human influences, surface-water impairment from parking-lot runoff, and unknown effects on surface-water quality from adjacent railroads. The concentration of nitrate in ground water from Lincoln Spring was greater than the State of Indiana standard for concentrations of nitrate in drinking water. Because only one well was sampled, no evaluation could be made of the source of recharge or nitrate to Lincoln Spring. Lead concentrations for the November 2001 and March 2002 surface-water samples from the stock pond, parking-lot runoff, and the unnamed ditch exceeded the chronic aquatic criteria set by the State of Indiana. Chronic aquatic criteria are set by the State of Indiana to ensure that the concentration of a substance does not produce chronic effects on aquatic organisms.

Concentrations of calcium, alkalinity, phosphorus, copper, iron, lead, and organic carbon were larger in the samples collected from the unnamed ditch and the parking-lot runoff than in those collected from ephemeral stream 3. Lead concentrations increased in samples between ephemeral stream 3 (detected in concentrations too small to be quantified) and the unnamed ditch. Lead concentrations in samples of parking-lot runoff were similar to those in samples from the unnamed ditch. Calcium concentrations increased in samples between ephemeral stream 3 and the unnamed ditch. Calcium concentrations in samples of parking-lot runoff were similar to those from the unnamed ditch. Similar concentration patterns were observed for alkalinity, iron, and organic carbon. These data indicate that parking-lot runoff is likely the primary source of iron, lead, and organic carbon in water from the unnamed ditch. It could not be determined whether the larger phosphorus and copper concentrations in parking-lot-runoff and the unnamed ditch samples, as

compared to those from ephemeral stream 3, resulted from a lack of analytical precision or a sampling-related interference.

The detection of concentrations of petroleum hydrocarbons in ground water from Lincoln Spring could indicate residual contamination from a nearby spill of diesel fuel that was reported in 1995. Verification of the sampling result, using the same analytical method and analysis of additional samples for trace volatile and semivolatile organic compounds, could indicate whether contamination from that spill persists in ground water beneath the park.

Surface-water-quality data for the park represent baseline conditions in relation to water quality reported from area streams, as cited in this report. In general, values of field characteristics and concentrations of most major ions and various nutrients in surface-water samples from the park were less than those reported for samples collected for other studies in adjacent areas to the park. Much of the surface-water-quality data from outside the park are from a 1979 study; the age of that data may be a factor in comparison with data in this study.

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**Tables 3, 5, 6, and 7**

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**Table 3.** Analytical constituents and reporting limits for samples collected during water-quality sampling at the Lincoln Boyhood National Memorial near Lincoln City, Indiana, 2001–02.

[-- , not available or known; USGS-NFM, U.S. Geological Survey National Field Manual for the Collection of Water-Quality Data; mg/L, milligram per liter;  $\infty$ S/cm, microsiemen per centimeter; °C, degree Celsius; CaCO<sub>3</sub>, calcium carbonate; lrl, lower reporting limit; ICP-AES, inductively-coupled plasma-atomic emission spectroscopy; IC, ion chromatography; mrl, method reporting limit; ASF, automated-segmented flow; SiO<sub>2</sub>, silica; N, nitrogen; P, phosphorus;  $\infty$ g/L, microgram per liter; GFAA, graphite furnace atomic absorption spectroscopy]

Constituent or property name	Chemical Abstracts Service identification number	Reporting limit	Reporting unit	Reporting-limit type	Analytical-method reference <sup>1</sup>	Analytical-method description
<b>Properties</b>						
Turbidity	--	--	Nephelometric turbidity unit	--	USGS-NFM, Chapter 6.7 (A)	Turbidimeter, field measurement
Dissolved oxygen	--	--	mg/L	--	USGS-NFM, Chapter 6.2 (A)	Multiparameter meter, field measurement
pH, field	--	--	Standard units	--	USGS-NFM, Chapter 6.4 (A)	Multiparameter meter, field measurement
Specific conductance	--	--	$\infty$ S/cm	--	USGS-NFM, Chapter 6.3 (A)	Multiparameter meter, field measurement
Temperature	--	--	°C	--	USGS-NFM, Chapter 6.1 (A)	Multiparameter meter, field measurement
Alkalinity	--	1	mg/L as CaCO <sub>3</sub>	--	USGS-NFM, Chapter 6.6 (A)	Incremental titration
<b>Major ions</b>						
Calcium, dissolved	7440-70-2	.012	mg/L	lrl	I-1472-87 (B)	ICP-AES
Magnesium, dissolved	7439-95-4	.008	mg/L	lrl	I-1472-87 (B)	ICP-AES
Potassium, dissolved	7440-09-7	.11	mg/L	lrl	3120-ICP (C)	ICP-AES
Sodium, dissolved	7440-23-5	.09	mg/L	lrl	I-1472-87 (B)	ICP-AES
Chloride, dissolved	16887-00-6	.33	mg/L	lrl	I-2057-85 (D)	IC
Fluoride, dissolved	16984-48-8	.11	mg/L	mrl	I-2327-89 (B)	ASF-Ion-selective electrode
Silica, dissolved	7631-86-9	.21	mg/L as SiO <sub>2</sub>	lrl	I-2700-89 (D)	Colorimetry, ASF, Molybdate blue
Sulfate, dissolved	14808-79-8	.11	mg/L	lrl	I-2057-85 (D)	IC

**Table 3.** Analytical constituents and reporting limits for samples collected during water-quality sampling at the Lincoln Boyhood National Memorial near Lincoln City, Indiana, 2001–02.—Continued

[-- , not available or known; USGS-NFM, U.S. Geological Survey National Field Manual for the Collection of Water-Quality Data; mg/L, milligram per liter;  $\infty$ S/cm, microsiemen per centimeter; °C, degree Celsius; CaCO<sub>3</sub>, calcium carbonate; lrl, lower reporting limit; ICP-AES, inductively-coupled plasma-atomic emission spectroscopy; IC, ion chromatography; mrl, method reporting limit; ASF, automated-segmented flow; SiO<sub>2</sub>, silica; N, nitrogen; P, phosphorus;  $\infty$ g/L, microgram per liter; GFAA, graphite furnace atomic absorption spectroscopy]

Constituent or property name	Chemical Abstracts Service identification number	Reporting limit	Reporting unit	Reporting-limit type	Analytical-method reference <sup>1</sup>	Analytical-method description
<b>Nutrients</b>						
Ammonia, dissolved	7664-41-7	0.01	mg/L as N	mrl	EPA 350.1 (E)	Colorimetry, ASF
Nitrite plus nitrate, dissolved	--	.047	mg/L as N	lrl	I-2545-90 (B)	Colorimetry, ASF, cadmium reduction-diazotization
Nitrite, dissolved	14797-65-0	.008	mg/L as N	lrl	I-2540-90 (B)	Colorimetry, ASF
Phosphorus, total	14265-44-2	.06	mg/L as P	lrl	I-4610-91 (F)	Colorimetry, ASF, microkjeldahl digestion
<b>Trace metals</b>						
Arsenic, total	7440-38-2	1.9	$\infty$ g/L	lrl	I-4063-98 (G)	GFAA
Cadmium, total	7440-43-9	.12	$\infty$ g/L	lrl	I-4138-89 (B)	GFAA
Chromium, total	7440-47-3	.8	$\infty$ g/L	lrl	I-3233-93 (H)	GFAA
Copper, total	7440-50-8	1.2	$\infty$ g/L	lrl	I-4274-89 (B)	GFAA
Iron, dissolved	7439-89-6	10	$\infty$ g/L	lrl	I-1472-87 (B)	ICP-AES
Lead, total	7439-92-1	1	$\infty$ g/L	lrl	I-4403-89 (B)	GFAA
Manganese, dissolved	7439-96-5	1.6	$\infty$ g/L	lrl	I-1472-87 (B)	ICP-AES
Nickel, total	7440-02-0	66	$\infty$ g/L	lrl	I-4471-97 (I)	ICP-AES
Selenium, total	7782-49-2	2	$\infty$ g/L	lrl	I-4668-98 (G)	GFAA
Silver, total	7440-22-4	7	$\infty$ g/L	mrl	I-4471-97 (I)	ICP-AES
Zinc, total	7440-66-6	25	$\infty$ g/L	mrl	I-4471-97 (I)	ICP-AES

**Table 3.** Analytical constituents and reporting limits for samples collected during water-quality sampling at the Lincoln Boyhood National Memorial near Lincoln City, Indiana, 2001–02.—Continued

[-- , not available or known; USGS-NFM, U.S. Geological Survey National Field Manual for the Collection of Water-Quality Data; mg/L, milligram per liter;  $\mu$ S/cm, microsiemen per centimeter; °C, degree Celsius; CaCO<sub>3</sub>, calcium carbonate; lrl, lower reporting limit; ICP-AES, inductively-coupled plasma-atomic emission spectroscopy; IC, ion chromatography; mrl, method reporting limit; ASF, automated-segmented flow; SiO<sub>2</sub>, silica; N, nitrogen; P, phosphorus;  $\mu$ g/L, microgram per liter; GFAA, graphite furnace atomic absorption spectroscopy]

Constituent or property name	Chemical Abstracts Service identification number	Reporting limit	Reporting unit	Reporting-limit type	Analytical-method reference <sup>1</sup>	Analytical-method description
<b>Organic substances in water</b>						
Organic carbon, total	--	0.6	mg/L	lrl	O-3100-83 (L)	Carbon analyzer
Petroleum hydrocarbons, total	--	2	mg/L	mrl	EPA 1664 NWQL TM 96.08 (K and L)	Hexane-extractable, gravimetric

<sup>1</sup>Method references:

- (A) U.S. Geological Survey, variously dated.
- (B) Fishman, 1993.
- (C) American Public Health Association, 1998.
- (D) Fishman and Friedman, 1989.
- (E) U.S. Environmental Protection Agency, 1993.
- (F) Patton and Truitt, 1992.
- (G) Jones and Garbarino, 1999.
- (H) McLain, 1993.
- (I) Garbarino and Struzeski, 1998.
- (J) U.S. Environmental Protection Agency, 2003.
- (K) U.S. Geological Survey, 1996.
- (L) Wershaw and others, 1987.

**Table 5.** Quality-assurance data for water-quality samples collected at the Lincoln Boyhood National Memorial near Lincoln City, Indiana, 2001–02.

[USGS, U.S. Geological Survey; mm/dd/yyyy, month/day/year; hhmm, hours and minutes; mg/L, milligram per liter; CaCO<sub>3</sub>, calcium carbonate; E, estimated value; <, less than; SiO<sub>2</sub>, silica; N, nitrogen; P, phosphorus; --, not measured or determined; µg/L, microgram per liter; C, carbon; *E. coli*, *Escherichia coli*; mL, milliliter; K, non-ideal colony count; all concentrations reported are as dissolved constituents except when noted]

USGS station-identification number	Site number (figs. 3 and 4)	Site name	Quality-assurance sample type	Date sampled (mm/dd/yyyy)	Time sampled (hhmm)	Calcium, dissolved (mg/L)	Magnesium, dissolved (mg/L)	Potassium, dissolved (mg/L)	Sodium, dissolved (mg/L)	Alka-linity (mg/L as CaCO <sub>3</sub> )	Chloride, dissolved (mg/L)
380701086595801	1	Stock pond	Equipment blank	07/10/2002	0945	E0.01	<0.008	<0.10	<0.09	2	<0.30
380707086595001	3	Parking-lot runoff	Equipment blank	11/29/2001	1156	<.01	<.008	<.10	<.09	<1	<.30
380707086595001	3	Parking-lot runoff	Equipment blank	03/26/2002	1215	<.01	<.008	<.10	<.09	2	<.30
380707086595101	4	Unnamed ditch	Sequential duplicate	11/29/2001	1436	25.7	5.23	2.59	1.63	69	2.1
380707086595101	4	Unnamed ditch	Sequential duplicate	03/26/2002	1451	20.1	4.41	1.44	2.14	53	1.59
380714086595501	5	Lincoln Spring	Sequential duplicate	07/10/2002	1320	69.0	26.9	8.08	47.1	6	127

**Table 5.** Quality-assurance data for water-quality samples collected at the Lincoln Boyhood National Memorial near Lincoln City, Indiana, 2001–02.—Continued

[USGS, U.S. Geological Survey; mm/dd/yyyy, month/day/year; hhmm, hours and minutes; mg/L, milligram per liter; CaCO<sub>3</sub>, calcium carbonate; E, estimated value; <, less than; SiO<sub>2</sub>, silica; N, nitrogen; P, phosphorus; --, not measured or determined; µg/L, microgram per liter; C, carbon; *E. coli*, *Escherichia coli*; mL, milliliter; K, non-ideal colony count; all concentrations reported are as dissolved constituents except when noted]

USGS station-identification number	Site number (figs. 3 and 4)	Site name	Quality-assurance sample type	Date sampled (mm/dd/yyyy)	Fluoride, dissolved (mg/L)	Silica, dissolved (mg/L as SiO <sub>2</sub> )	Sulfate, dissolved (mg/L)	Ammonia, dissolved (mg/L as N)	Nitrite plus nitrate, dissolved (mg/L as N)	Nitrite, dissolved (mg/L as N)	Phosphorus, total (mg/L as P)
380701086595801	1	Stock pond	Equipment blank	07/10/2002	<0.1	<0.2	<0.1	0.01	E0.04	<0.008	<0.06
380707086595001	3	Parking-lot runoff	Equipment blank	11/29/2001	<.1	<.2	<.1	--	<.05	<.008	<.06
380707086595001	3	Parking-lot runoff	Equipment blank	03/26/2002	<.1	<.2	<.1	<.01	<.05	<.008	<.06
380707086595101	4	Unnamed ditch	Sequential duplicate	11/29/2001	E.1	11.8	21.8	--	.05	<.008	.07
380707086595101	4	Unnamed ditch	Sequential duplicate	03/26/2002	E.1	11.1	20.9	<.01	.09	E.004	E.04
380714086595501	5	Lincoln Spring	Sequential duplicate	07/10/2002	.1	24.4	156	.18	17.4	.01	<.06

**Table 5.** Quality-assurance data for water-quality samples collected at the Lincoln Boyhood National Memorial near Lincoln City, Indiana, 2001–02.—Continued

[USGS, U.S. Geological Survey; mm/dd/yyyy, month/day/year; hhmm, hours and minutes; mg/L, milligram per liter; CaCO<sub>3</sub>, calcium carbonate; E, estimated value; <, less than; SiO<sub>2</sub>, silica; N, nitrogen; P, phosphorus; --, not measured or determined; µg/L, microgram per liter; C, carbon; *E. coli*, *Escherichia coli*; mL, milliliter; K, non-ideal colony count; all concentrations reported are as dissolved constituents except when noted]

USGS station-identification number	Site number (figs. 3 and 4)	Site name	Quality-assurance sample type	Date sampled (mm/dd/yyyy)	Arsenic, total (µg/L)	Cadmium, total (µg/L)	Chromium, total (µg/L)	Copper, total (µg/L)	Iron, dissolved (µg/L)	Lead, total (µg/L)	Manganese, dissolved (µg/L)
380701086595801	1	Stock pond	Equipment blank	07/10/2002	<2	<0.1	<0.8	<1	<10	<1	<2
380707086595001	3	Parking-lot runoff	Equipment blank	11/29/2001	<2	<.1	<.8	1.7	<10	<1	<2
380707086595001	3	Parking-lot runoff	Equipment blank	03/26/2002	<2	<.1	<.8	<1	<10	<1	<2
380707086595101	4	Unnamed ditch	Sequential duplicate	11/29/2001	E2	<.1	E.5	2.3	188	6	8.1
380707086595101	4	Unnamed ditch	Sequential duplicate	03/26/2002	<2	<.1	E.5	1.5	127	6	13.9
380714086595501	5	Lincoln Spring	Sequential duplicate	07/10/2002	<2	<.1	<.8	10.7	28	1	316

**Table 5.** Quality-assurance data for water-quality samples collected at the Lincoln Boyhood National Memorial near Lincoln City, Indiana, 2001–02.—Continued

[USGS, U.S. Geological Survey; mm/dd/yyyy, month/day/year; hhmm, hours and minutes; mg/L, milligram per liter; CaCO<sub>3</sub>, calcium carbonate; E, estimated value; <, less than; SiO<sub>2</sub>, silica; N, nitrogen; P, phosphorus; --, not measured or determined; µg/L, microgram per liter; C, carbon; *E. coli*, *Escherichia coli*; mL, milliliter; K, non-ideal colony count; all concentrations reported are as dissolved constituents except when noted]

USGS station-identification number	Site number (figs. 3 and 4)	Site name	Quality-assurance sample type	Date sampled (mm/dd/yyyy)	Nickel, total (µg/L)	Selenium, total (µg/L)	Silver, total (µg/L)	Zinc, total (µg/L)	Petroleum hydrocarbons, total (mg/L)	Organic carbon, total (mg/L as C)	Suspended sediment, total (mg/L)
380701086595801	1	Stock pond	Equipment blank	07/10/2002	<70	<2	<7	<20	2	<0.6	--
380707086595001	3	Parking-lot runoff	Equipment blank	11/29/2001	--	<2	--	<20	<2	<.6	--
380707086595001	3	Parking-lot runoff	Equipment blank	03/26/2002	<70	<2	<7	<20	<2	<.6	--
380707086595101	4	Unnamed ditch	Sequential duplicate	11/29/2001	--	E1	--	<20	<2	9.7	23
380707086595101	4	Unnamed ditch	Sequential duplicate	03/26/2002	<70	<2	<7	<20	<2	5.1	19
380714086595501	5	Lincoln Spring	Sequential duplicate	07/10/2002	<70	<2	<7	<20	2	3.1	.3

**Table 5.** Quality-assurance data for water-quality samples collected at the Lincoln Boyhood National Memorial near Lincoln City, Indiana, 2001–02.—Continued

[USGS, U.S. Geological Survey; mm/dd/yyyy, month/day/year; hhmm, hours and minutes; mg/L, milligram per liter; CaCO<sub>3</sub>, calcium carbonate; E, estimated value; < , less than; SiO<sub>2</sub>, silica; N, nitrogen; P, phosphorus; -- , not measured or determined; µg/L, microgram per liter; C, carbon; *E. coli*, *Escherichia coli*; mL, milliliter; K, non-ideal colony count; all concentrations reported are as dissolved constituents except when noted]

<b>USGS station-identification number</b>	<b>Site number (figs. 3 and 4)</b>	<b>Site name</b>	<b>Quality-assurance sample type</b>	<b>Date sampled (mm/dd/yyyy)</b>	<b><i>E. coli</i> bacteria (colonies/100 mL)</b>
380701086595801	1	Stock pond	Filter blank	07/10/2002	0
380701086595801	1	Stock pond	Field blank	07/10/2002	0
380714086595501	5	Lincoln Spring	Sequential duplicate	07/10/2002	K3
380714086595501	5	Lincoln Spring	Filter blank	07/10/2002	0
380714086595501	5	Lincoln Spring	Process blank	07/10/2002	0

**Table 6.** Surface-water-quality characteristic and bacteria data from sites near the Lincoln Boyhood National Memorial near Lincoln City, Indiana, 1979 and 2000.

[USGS, U.S. Geological Survey; mm/dd/yyyy, month/day/year; hhmm, hours and minutes; ft<sup>3</sup>/s, cubic foot per second; NTU, nephelometric turbidity unit; mg/L, milligram per liter; ∞S/cm, microsiemen per centimeter; °C, degree Celsius; *E. coli*, *Escherichia coli*; mL, milliliter; N/A, not applicable; N/R, not reported; --, not measured or determined; SR, State Road; K, non-ideal colony count]

USGS station-identification number	Site name (this report and other published reports)	Data source <sup>1</sup>	Date(s) sampled (mm/dd/yyyy)	Time sampled (hhmm)	Discharge (ft <sup>3</sup> /s)	Turbidity (NTU)	Dissolved oxygen (mg/L)	pH, field (standard units)	Specific conductance (∞S/cm)	Temperature (°C)	<i>E. Coli</i> bacteria, (colonies/100 mL)
N/A	Site 260 (Little Pigeon Creek near East 1000 Road)	(1)	03/12-21/1979	N/R	--	--	--	6.8	340	12.8	--
N/A	Site 273 (Little Pigeon Creek near SR 245)	(1)	03/12-21/1979	N/R	--	--	8.8	6.8	510	18.9	--
N/A	Site 274 (Crooked Creek near SR 162)	(1)	03/12-21/1979	N/R	--	--	9.1	7.0	440	18.3	--
N/A	Site 277 (Buckhorn Creek near US Highway 231)	(1)	03/12-21/1979	N/R	--	--	9.5	6.3	270	14.6	--
380338087054900	Site 267 (Little Pigeon Creek near Tennyson)	(1)	03/12-21/1979	N/R	--	--	--	6.2	280	12.8	--
380338087054900	Site 267 (Little Pigeon Creek near Tennyson)	(1)	05/31/1979	1200	5.1	--	3.5	7.4	580	20.0	--
380338087054900	Site 267 (Little Pigeon Creek near Tennyson)	(2)	10/17/1979	0830	--	--	6.0	6.7	570	12.0	--

**Table 6.** Surface-water-quality characteristic and bacteria data from sites near the Lincoln Boyhood National Memorial near Lincoln City, Indiana, 1979 and 2000.—Continued  
 [USGS, U.S. Geological Survey; mm/dd/yyyy, month/day/year; hhmm, hours and minutes; ft<sup>3</sup>/s, cubic foot per second; NTU, nephelometric turbidity unit; mg/L, milligram per liter;  $\infty$ S/cm, microsiemen per centimeter; °C, degree Celsius; *E. coli*, *Escherichia coli*; mL, milliliter; N/A, not applicable; N/R, not reported; --, not measured or determined; SR, State Road; K, non-ideal colony count]

USGS station-identification number	Site name (this report and other published reports)	Data source <sup>1</sup>	Date(s) sampled (mm/dd/yyyy)	Time sampled (hhmm)	Discharge (ft <sup>3</sup> /s)	Turbidity (NTU)	Dissolved oxygen (mg/L)	pH, field (standard units)	Specific conductance ( $\infty$ S/cm)	Temperature (°C)	<i>E. Coli</i> bacteria, (colonies/100 mL)
380317086541801	Site 34 (Crooked Creek at SR 245 at Lamar)	(3)	07/12/2000	0925	--	52	1.3	7.0	462	26.0	280
380317086541801	Site 34 (Crooked Creek at SR 245 at Lamar)	(3)	07/19/2000	0900	--	90	2.9	7.2	549	25.0	700
380317086541801	Site 34 (Crooked Creek at SR 245 at Lamar)	(3)	07/26/2000	0950	--	45	2.3	7.2	736	21.5	90
380317086541801	Site 34 (Crooked Creek at SR 245 at Lamar)	(3)	08/02/2000	0950	--	33	8.8	7.6	513	24.5	740
380317086541801	Site 34 (Crooked Creek at SR 245 at Lamar)	(3)	08/09/2000	1010	--	68	2.8	6.9	357	24.0	K13,000
03304055	Site 35 (Little Pigeon Creek at SR 161 at Midway)	(3)	07/12/2000	0835	--	20	4.3	7.5	1,800	26.0	200
03304055	Site 35 (Little Pigeon Creek at SR 161 at Midway)	(3)	07/19/2000	0815	--	27	4.7	7.6	2,000	25.5	260
03304055	Site 35 (Little Pigeon Creek at SR 161 at Midway)	(3)	07/26/2000	0855	--	20	5.6	7.6	2,000	22.0	120
03304055	Site 35 (Little Pigeon Creek at SR 161 at Midway)	(3)	08/02/2000	0905	--	59	4.2	6.8	391	23.0	570
03304055	Site 35 (Little Pigeon Creek at SR 161 at Midway)	(3)	08/09/2000	0910	--	210	5.4	6.8	302	23.5	5,200

<sup>1</sup>Data references:

- (1) Renn and others, 1980.
- (2) Renn, 1983.
- (3) Silcox and others, 2002.

**Table 7.** Surface-water-quality data from sites near the Lincoln Boyhood National Memorial near Lincoln City, Indiana, 1979.

[USGS, U.S. Geological Survey; mm/dd/yyyy, month/day/year; hhmm, hours and minutes; mg/L, milligram per liter; CaCO<sub>3</sub>, calcium carbonate; SiO<sub>2</sub>, silica; N, nitrogen; P, phosphorus; --, not measured or determined; µg/L, microgram per liter; <, less than; M, presence verified but not quantified; all concentrations reported are as dissolved constituents, except when noted]

USGS station-identification number	Site name (this report and other published reports)	Data source <sup>1</sup>	Date sampled (mm/dd/yyyy)	Time sampled (hhmm)	Hardness (mg/L as CaCO <sub>3</sub> )	Calcium, dissolved (mg/L)	Magnesium, dissolved (mg/L)	Potassium, dissolved (mg/L)	Sodium, dissolved (mg/L)	Alkalinity (mg/L as CaCO <sub>3</sub> )
380338087054900	Site 267 (Little Pigeon Creek near Tennyson)	(1)	05/31/1979	1200	210	54	18	4.5	36	93
380338087054900	Site 267 (Little Pigeon Creek near Tennyson)	(2)	10/17/1979	0830	170	41	16	4.2	31	61

USGS station-identification number	Site name (this report and other published reports)	Data source <sup>1</sup>	Date sampled (mm/dd/yyyy)	Chloride, dissolved (mg/L)	Fluoride, dissolved (mg/L)	Silica, dissolved (mg/L as SiO <sub>2</sub> )	Sulfate, dissolved (mg/L)	Nitrite plus nitrate, dissolved (mg/L as N)	Phosphorus, dissolved (mg/L as P)
380338087054900	Site 267 (Little Pigeon Creek near Tennyson)	(1)	05/31/1979	23	0.2	5.4	170	0.96	0.02
380338087054900	Site 267 (Little Pigeon Creek near Tennyson)	(2)	10/17/1979	27	.2	11	130	4.9	--

**Table 7.** Surface-water-quality data from sites near the Lincoln Boyhood National Memorial near Lincoln City, Indiana, 1979.—Continued

[USGS, U.S. Geological Survey; mm/dd/yyyy, month/day/year; hhmm, hours and minutes; mg/L, milligram per liter; CaCO<sub>3</sub>, calcium carbonate; SiO<sub>2</sub>, silica; N, nitrogen; P, phosphorus; --, not measured or determined; µg/L, microgram per liter; <, less than; M, presence verified but not quantified; all concentrations reported are as dissolved constituents, except when noted]

USGS station-identification number	Site name (this report and other published reports)	Data source <sup>1</sup>	Date sampled (mm/dd/yyyy)	Arsenic, total (µg/L)	Cadmium, total (µg/L)	Chromium, total (µg/L)	Copper, total (µg/L)	Iron, dissolved (µg/L)	Lead, total (µg/L)	Manganese, dissolved (µg/L)
380338087054900	Site 267 (Little Pigeon Creek near Tennyson)	(1)	05/31/1979	1	<2	<10	M	30	--	1,600
380338087054900	Site 267 (Little Pigeon Creek near Tennyson)	(2)	10/17/1979	4	0	20	M	50	3	260

USGS station-identification number	Site name (this report and other published reports)	Data source <sup>1</sup>	Date sampled (mm/dd/yyyy)	Nickel, total (µg/L)	Selenium, total (µg/L)	Zinc, total (µg/L)	Organic carbon, total (mg/L)	Suspended sediment (mg/L)
380338087054900	Site 267 (Little Pigeon Creek near Tennyson)	(1)	05/31/1979	--	<1	--	10	--
380338087054900	Site 267 (Little Pigeon Creek near Tennyson)	(2)	10/17/1979	M	0	10	5.4	26

<sup>1</sup>Data references:

(1) Renn and others, 1980.

(2) Renn, 1983.